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CRUCIBLES OF BLAST FURNACES.

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The Lecturer was introduced by the Secretary, and spoke as follows:

In a furnace for producing pig iron, the lower part is divided as follows:

(1.) The bosh or slope down to the tuyeres.

(2.) The crucible from the tuyeres down to the hearth.

(3.) The hearth, or bottom.

The bosh consists of, usually, an eighteen-inch wall with a series of inch cooling pipe against the outside of the wall, and a wrought-iron bosh jacket against the pipe. This jacket supports the walls and prevents them from spreading, while the coil with its water circulation maintains the walls an uniform thickness of about twelve to

fourteen inches, the first four to six inches melting off until the chilling influence of the coil prevents any further melting. It is better to use a thirteen and one-half–inch wall at once, but the conservatism of furnacemen demands eighteen inches, thirteen and one-half inches has been tried and does well. From the bottom of this bosh jacket to a foot below the tuyere is placed a cast-iron tuyere jacket with one-inch cooling pipe cast in it. It has the requisite number of holes for the tuyeres and breasts, while under each tuyere is placed a small cinder hole to bleed the tuyeres in event of a pocket forming in front of the tuyere and retaining the cinder which, if not drawn off, will close the tuyere. The wall inside of this jacket is eighteen inches usually, but could be thirteen and one-half inches, same as on the bosh. This crucible jacket is made in sections held together with key bolts and has a trough at the bottom to hold water and chill the crucible wall below. Each tuyere opening has a projection extending inside of jacket, which holds and retains the tuyere breasts in position, independent of the walls if they should melt away. This obviates the old trouble of a tuyere drooping at the nose when the walls melt.

From the trough of the tuyere jacket, down to twenty-four inches below the hearth, is placed a heavy wrought-iron crucible jacket made in sections and clamped together. At the front is placed the dam or iron notch, at the back is placed the cinder notch, both being supported independent of the walls by the jacket. Near the back of this jacket, at the hearth level, are placed two small iron notches for purposes to be hereafter explained. The wall inside of this jacket consists of three nine-inch courses of best fire brick, and between each of them the vertical joints are made two inches thick, composed of crushed fire brick and clay driven tight in these vertical joints. These joints prevent any cracking of the brickwork of each nine-inch course from extending through to its neighbor, the object being to prevent the iron from leaking through to the jacket. A similar joint, but without fire clay, is placed between the outside course of brickwork and the crucible jacket.

The hearth or bottom is built in the foundation of the furnace, and is composed of the best fire brick interlocked to prevent the iron floating them up. The centre of the hearth inside of the crucible is depressed about sixteen inches, forming a pool for the

iron, which being filled up remains during the blast. The ground around the crucible jacket is usually filled up, say, twelve inches above the hearth.

The fuel passing down the bosh is oxidized at the tuyere, converted to carbonic acid, and is immediately reconverted by the glowing fuel to carbonic oxide. At a level of about three feet above the tuyeres, there practically exists a strong reducing atmosphere of carbonic oxide. This atmosphere of carbonic oxide prevents the intensely hot iron sponge or reduced ore further up the bosh from burning back to the oxide of iron, as the sponge at this high heat will quickly decompose carbonic acid and seize the atom of oxygen from carbonic acid. This atom of oxygen with the atom of iron will appear in a brownish red smoke at the chimney top. The lower part of the furnace is filled with glowing coal, through which the shots of molten cinder and iron fall, and are collected in the crucible. The liquid cinder being lighter, floats on the molten iron until it rises to the level of the cinder notch where it is drawn off. The cinder notch is placed back of the furnace to equalize the heat across the hearth and keep the iron in the back part of the hearth in a fluid state. When the iron and cinder notch are both front, the excess of heat melts away the walls, keeps the front tuyeres hotter, which causes more blast to enter, and makes the furnace drive faster on the front. When the iron has risen nearly to the level of the cinder notch, it is drawn out through the dam at the front. The iron tap hole in the dam is stopped with a large ball of clay, which is dug out when the iron is tapped off. Adjoining the iron notch is a large cast-iron trough washed with clay through which the iron flows to the skimmer at the end of the trough. This skimmer separates the cinder or any dirt floating on top of the iron, leaving the iron flow into the pig bed bright and clean.

Around the bosh, below the mantel, is placed the circular-blast distributing pipe, having a branch to each tuyere. The connection between the tuyeres and branches are made with a globe-faced flexible tuyere pipe. The tuyeres are spaced evenly and their number is determined, (1) by the volume of air; (2) by the diameter of the nose, which should not exceed four and one-half inches for anthracite, and five and one-half inches for coke; this allows for four-inch and five-inch nozzles, respectively. The

velocity of the blast (engine measurement) for anthracite should be 15,000 feet per minute, and for coke 10,000 feet. With a slower velocity of blast, the cinder clogs the nose of the tuyere quickly.

These rules give more tuyeres than in the old practice, and smaller nozzles, but it admits of a larger hearth, disseminates the blast more evenly across it, and lowers the zone of fusion by the increase in size of hearth. An excess of tuyere area allows greater part of the blast to pass those tuyeres that work most freely, and the hotter the fuel near a tuyere the greater is the consumption of air at that tuyere. The result is, that this particular tuyere will take, say, twice its volume of air and rob the others to that extent. Sometimes two or more will combine and rob the rest. When this occurs, the heat works up the bosh, tilts or pushes up one side of the zone of fusion, causes irregular working, and forces the heat up that side of the furnace to the top, the gas escaping without doing its duty in reduction, and robbing the furnace of its heat. These passages upward are constantly occurring, and are worse with large tuyeres. They can be minimized by smaller tuyeres. The existence of these passages can be proven by placing at equal distance, say, six pyrometers in the side of the furnace at stock line, when it will be found that the different pyrometers will vary 200° from time to time, by the heat shifting around just as one or the other set of tuyeres takes the blast, and also by the channels cut in the furnace lining, which show when the furnace goes out of blast.

These passages throw the zone of fusion out of position, let raw stock down through that zone, producing irregular iron scouring cinder, and burning these particular tuyeres by the great flow of iron over them. The tuyeres must be so arranged and proportioned that they burn off the descending fuel column in such manner that across the top of the bosh the column will flow down evenly. To do this the tuyere must burn off the descending column at the bottom of bosh more rapidly at the bosh walls than in the centre, owing to the contraction of the bosh. To burn the fuel more rapidly at the bosh walls requires them to be well protected from melting, hence the use of the water coil before mentioned between the bosh jacket and the bosh walls.

The diameter of the crucible is determined by the volume of blast and the fuel, the tuyeres must be so proportioned that while they burn the fuel more rapidly at the walls, yet the blast must have

sufficient projection to reach the centre of the fuel column and prevent a core of fuel. Nozzles must be varied to meet any change in the volume of blast to insure a proper penetration. Running a long bar through the tuyere will soon show any core in the centre of the furnace.

The size of the nozzle determines the pressure to a limited extent only. It is the internal condition of the furnace that gives the pressure. This fact is too often lost sight of in speaking of nozzles.

Building a fire on the hearth at home, it burns slowly at first, as the walls absorb the heat so rapidly that the temperature is kept too low for perfect combustion of the gas passing off from the fuel. When the walls are fully saturated with heat, the fire burns vigorously, as, there being no heat absorption by the walls, the gas is burned to its full equivalent of heat. To keep this fire perfect, nothing is required but to add wood and remove the ashes. If some water is poured on the hearth stone, steam is generated, heat is absorbed, combustion is imperfect, the gas escapes unconsumed and the vigorous fire becomes dull. Again, let the fire burn fiercely and close the chimney damper, the gas now escapes unconsumed and the fire becomes dull. In the crucible of a blast furnace, when water leaks from a tuyere, heat is absorbed and the temperature lowered. This prevents perfect combustion at the tuyere, which also lowers the heat. If the crucible continues to cool off, the iron chills and eventually the cinder also. This cooling can also come from too heavy a burden or lowering the heat in the hot blast, etc.

Slacking the blast will heat up the crucible locally for a short time, but eventually will cool it if the equilibrium of heat absorbed and heat generated is lost by slower combustion. The blast must be increased fast as possible. If, on the other hand, the furnace scaffolds or chokes with dust, sufficient air cannot be got through, as the dust resists the blast pressure, and the heat generated being less than the heat absorbed, the equilibrium is lost and the crucible chills. This compares with the chimney and hearth before quoted. When the heat in the crucible is lowered, the zone of fusion soon feels the loss, and not melting rapidly enough, the disintegrated stock collects above it and increases the pressure, as will be shown elsewhere. This loss of heat makes the zone of fusion pasty and

sticky, which prevents the passage of the fuel as well as the ore and stone. The harder the fuel, the more difficult is it to restore the heat to the zone of fusion, hence the difficulty of anthracite practice.

There are two forces at work in the crucible.

(1.) Heat generation by combustion of the fuel assisted by the hot blast;

(2.) Heat absorption by the tuyere water and all water connections, by radiation from walls, conduction through hearth and foundation, by blowing out at cinder notch and iron notch, by the gas going upward, by the cinder and by the iron. The loss by tuyere water and all water connection by radiation and conduction is a constant loss going on, whether the furnace is running or standing. It consumes the heat from about one-sixth the total fuel used.

The deep hearth and thick crucible walls act as a regenerator to store up large volumes of heat and prevent the crucible from suddenly chilling. So great is this heat storage that the ground outside of the foundation is from 250° to 300° temperature three feet below the surface.

The blast or air entering the furnace is heated up to say 1,200° to 1,400° by regenerative stoves.* The temperature of the crucible above the tuyere, say, three feet, is about 2,900° when making No. 3 iron. Immediately in front of the tuyere there is a lower temperature caused by the entering blast, but at a short distance from the end of the tuyere, where the blue point of the blow-pipe flame is formed, the highest heat of carbonic acid plus the heat of blast, say, 6,000°, is reached. This heat is immediately lowered by the conversion of the carbonic acid to carbonic oxide. Above the tuyeres, for a distance of some feet, varying with the volume of blast, there is the bed of glowing coal extending from the zone of fusion down to the hearth through which the shots of falling iron and cinders from the zone of fusion percolate and fill

* A temperature of blast of 800° will ignite charcoal, 900° will ignite coke, and 1,300° will ignite anthracite. The porous character of charcoal and coke gives an interior combustion, while anthracite burns on the surface only, and one-eighth of an inch below the surface it is found untouched by combustion. Hence larger hearths and more surface of contact is required to consume it.

the interstices between the fuel in the crucible. In this percolation through the glowing fuel the unreduced oxide is reduced, but any escaping through the fuel is taken up by the slag unless it happens that the ore is very refractory and of greater specific gravity than the slag when it passes through the slag and is reduced by the carbon in the hearth. This destroys the graphitic carbon in the iron and lowers its quality.

These stray lumps of ore are occasionally found at the tuyeres, especially if the stock in the furnace is slipping. On the more perfect reduction of the oxide above the tuyeres depends the quality or number of the iron. The higher the heat the better the reduction.

That a certain amount of the oxide escapes reduction is shown by the slag analysis, and is due to the blast not working up uniformly at all points of the crucible. Cinder from No. 1 slag contains from traces to one per cent. protoxide, and from No. 5 iron two to eight per cent. protoxide. Variations from the above exist, owing to the presence or absence of sulphur, phosphorus, manganese, etc. The high heat caused by the larger amount of fuel used in making No. 1, and the contact of the iron with the solid fuel in the hearth reduces all oxide and changes part of the combined carbon in the pig to graphitic carbon, which is the cause of the better grade of iron. Care must be taken not to get too hot, or the carbon in its greed for oxygen will decompose the silica in the fuel to silicon, which, uniting with the iron, gives a soft weak pig, of a whitish fracture. The utmost skill of the founder is required here.

The glowing fuel in the crucible is gradually consumed in the formation of graphite or kish, by reduction of oxide of iron or by oxidation when blowing out after the iron and cinder are drawn off, and is replenished by the downward flow of the fuel.

The iron slag and fuel in crucibles is chilled at times by water leaking into them from the tuyere breasts or other water connections, by cold blast, by too heavy a burden of ore, and by long stoppages, etc. As soon as the furnace man finds the least indication of cooling, the burden of ore and stone must be lightened or the blast heat raised to restore the heat. Crucibles generally chill up to the cinder notch, but sometimes higher, when pockets are formed in front of the tuyeres by the blast. If these pockets do

not communicate with each other to let the slags flow around to the cinder notch, the holes in the jacket must be opened to free the tuyere from slag. Heretofore, this mass has been melted out by the flow of iron and cinder over it, requiring from one to four weeks to get rid of it and producing white and mottled iron during that time. At present, a coal oil blowpipe is used, which, in thirty hours, will restore the crucible to a normal condition. This blowpipe consists of a three and one-half inch clay tuyere, to which is attached a four-inch gas pipe seven feet long, and a section of four-inch hose to supply the blast. A one-fourth-inch pipe leads the oil from the tunnel-head into the blowpipe where it is vaporized by the rebounding heat in front of tuyere. The vapor passing into the blast current is ignited and directed against the iron notch, which it soon melts out, a little soda or salt being used to flux and assist the melting.

Before starting the blowpipe, the iron trough should be removed and a good bed of sand put in its place, as the melted material on cooling is extremely hard and fuses with anything with which it comes in contact. Only light kerosene or torch-oil should be used and must be well mixed with the air before burning. A pressure of four or five pounds of blast is required to project the flame well forward, and prevent burning the nose of the blowpipe. It is best to lay some old fire brick in front of the iron notch, or hole operated on, leaving through the brick an opening for the pipe to play through and slag to run out. These bricks reflect or throw back the heat into the hole, and cause a more rapid melting.

When the crucible is chilled above the tuyeres, one blowpipe is started on the cinder notch and one on one of the tuyeres nearest the cinder notch. In a short time, a passage is melted from the notch to the tuyere. The blowpipes are then put to work on the next tuyeres each side, and blast is turned on the tuyere melted out. As each tuyere melts out and communicates with the cinder notch, blast is turned on them, which, in a short time, melts out the crucible in front of the tuyeres. The chilled material is mostly fuel and cinder with a little iron, but should there not be fuel enough to keep up combustion, a spray of oil must be used, as hereafter explained.

It takes some time to get the opening hot and get the right proportion of oil, as there is generally too much used, which lowers

the temperature. As the opening becomes hotter, more oil can be used. A loud humming noise denotes when the proper quantity is used. A screen must be placed over the upper end of the oil pipe to prevent dirt choking the pipe and cock. A round way cock only should be used.

The melted part is removed as soon as it flows out on the bed of sand. If the fused material is allowed to chill before removal, a little dynamite judiciously applied will shatter it. Dynamite is also used to open a passage from a tuyere through the chilled material into the live coal beyond. It should only be handled by an expert. The two extra iron notches at the back of the furnace are then opened, and blowpipes started to melt them out. This melting proceeds on in until the centre is reached. By care, the mass can be melted out, leaving a roof above to support the cinder and iron flowing through the cinder notch, the blast being kept on the furnace during this time. The back iron notches are now closed, and the front blowpipe is directed up against the roof, melting it, letting the iron and cinder down, which flows through the iron notch, the cinder notch having been previously closed to accumulate a large flush of cinder. This large flush soon melts away the roof, and when the flush is out the iron notch is closed until another flush collects, when it is again drawn off by the iron notch, and repeated until the iron becomes gray, when the cinder notch can be opened as usual. The white iron made during this time flows sluggishly, and it is best to run it out with the cinder on top of the iron, which keeps it hot and gets it into the pig bed in better shape.

During the time the blowpipes are melting out the crucible, they are heating it up, so that on melting through the roof the cinder and iron are kept fluid in it. As the iron becomes grayer, the volume of blast is increased until No. 2 iron is reached, then the burden is increased until the normal burden is reached, when the full volume of blast is used. The heat must be built up step by step, as surely and as fast as possible.

The old iron left in the hearth by the chill must be carefully worked out before good gray iron can be made, as this old material being white iron, will absorb the graphite of the gray iron and lower its grade even when a light burden is used. This difficulty often causes the founder to lighten his burden again, when by a

little patience the iron would improve in quality as the old iron is worked out. A light burden is an evil that must be heroically met on the score of economy.

Without a clean hot crucible no good iron can be made, and special attention must be given at all times to maintaining the equilibrium of heat and proper temperature in it. At a certain heat, kish or graphite is formed in the crucible from the fuel, which gives a strong, dark iron. At a higher heat, graphite is replaced by silicon. As some of the graphite always escapes with the slag, it can be seen, and gives the furnace man notice of a good temperature for No. 1 and No. 2 iron, unless sulphur is in excess. When strict attention is paid to the heat, there is no difficulty in working titanic ores, as all they require is a crucible hot enough to melt the cinder, and not too hot, or the titanic acid is reduced, which clogs up the hearth. The two extremes must be avoided, and, with care, there is ample range between them. These titanic ores make excellent iron for forge purposes.

Crucibles are often chilled by a shower of granular and dusty stock, which, when at a bright red heat, flows like fine shot. These granules surrounding the fuel in the crucible prevent free access of air to the fuel, and combustion goes on slowly. The constant loss of heat from the hearths by tuyere water, radiation, etc., overbalances the heat generated, and the crucible chills. At a level, say, three to six feet above the top of the bosh, is the zone of fusion resting on the bed of glowing fuel below. This zone is constantly forming and melting away, and, taken as a whole, is in a pasty condition, the top being slightly pasty and the bottom liquid. When ores are used that disintegrate rapidly to a granular state, they rattle down through the stock ahead of the fuel they are charged with, and rest on the zone of fusion. If this zone does not melt the fine stock as rapidly as it accumulates, it piles up and, pressing heavily on the zone, retards the passage of the ascending gas. The blast pressure goes up with this accumulation of fine material, and when the engine is not powerful enough the furnace chokes and irregular working begins.

Blowing at as high a pressure as possible for some time will generally force an opening up through the zone, which relieves the pressure and causes the blowing engine to run off. The engine is slacked which reduces the pressure in the opening, and lets the

fine material down to the crucible as stated: at the same time part of the dust is blown over into the flues, and immense volumes escape at the chimney. While blowing against the zone of fusion the fuel below it consumes, if there is any escape of gas through

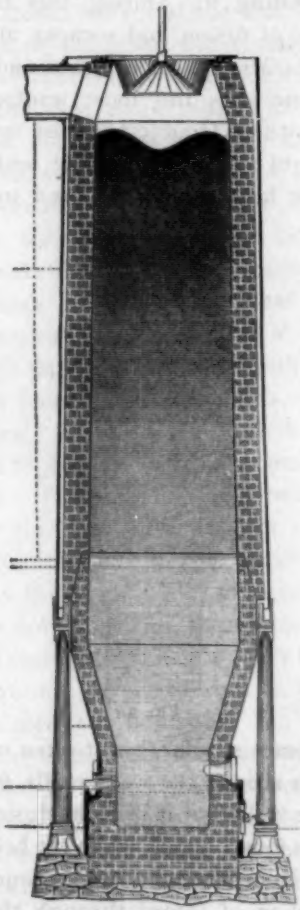


FIG. 1.

the zone, leaving a cavity, and the stock will not settle, the blast is thrown off suddenly, and if this does not cause the stock to settle, a hole is cut through the side of the furnace into the cavity and a torpedo exploded in it, which usually answers the purpose. This is a final resort, but the blowing must not be continued too

long, or there will not be coal enough left to restore the heat to the hearth. When the furnace slips or settles some distance, say ten to fifteen feet, the zone of fusion is disarranged, the cinder is forced back in the tuyere pipe, and the bosh chilled by the cold stock filling it. During this trouble, little or no gas passes the zone of fusion and escapes at the top of furnace to the stoves and boilers to make steam and heat the blast, and this just at the time it is the most wanted. Extra firing, at boilers and stoves, with its trouble and cost must then be resorted to. When the heat of the bosh, crucible, and stoves, are not too much exhausted, the heat can be restored to the zone of fusion

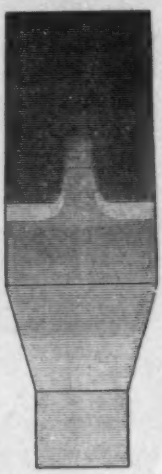


FIG. 2.

and the process becomes regular, but it often occurs that the edge of the zone of fusion around the walls chills, forming a ring which sets so firmly on the wall that it remains during the blast, and on going out the ring is found intact, while the brick above and below it have melted back from fifteen to twenty-four inches.

The opening spoken of, forced through the zone of fusion, is generally in the centre (see *Fig. 2*), but sometimes is found on the side against the wall. With this limited opening no good work can be done, and the obstruction must be removed by blowing it down with explosives, melting it out with the blowpipe through openings on the sides of the furnace, or by digging the stock out of the furnace. This trouble from fine material some-

times comes from a scaffold or scab on the bosh, which, by attrition or heat, becomes loose and leaves the fine stock back of it flow down to the crucible. This is not, however, preceded by a high blast pressure and a sudden easing up of the pressure. As soon as this dust material arrives at the crucible, it must be either melted and run out, or shovelled out through the tuyere breast. A small fine spray of coal oil through each tuyere that is working will help to melt the dust more rapidly and get the hearth hot quicker. This dust obstruction can also come from using too much fine ore; and slow driving with a large bosh favors its accumulation. In the absence of scaffolds we must look to the loss of heat in the zone of fusion for the cause of high pressure. With high blast pressures, the loss in leakage of blast is enormous, and the more leakage the less is the heat generated, while the constant loss goes on exhausting the heat of the crucible.

Running through part of the veins of anthracite and bituminous coal are streaks of bone and slate which, reaching the furnace, cause cold crucibles. There is less carbon in a ton of this fuel, while the bone is a highly refractory slag material, requiring a hot crucible to melt it. This bone, or slate, being of about the same specific gravity as the slag, follows down into the crucible after each cast, gradually filling it, except a pocket in front of the iron notch. As soon as this pocket fills with iron, the latter flows out through the cinder notch, melting the notch and spoiling the iron. Casting has to be resorted to probably every hour in this case. The blowpipes should at once be put to work on the extra iron notches back of furnace to melt the bone out. In many cases it lies in the crucible in a dry state and can be shovelled out. When a tuyere uses too much blast, it will sometimes build a lump of iron on the wall above it. The oxygen of the blast decarbonizes it, forming a pasty wrought-iron mass. At times this comes loose, slides down into the crucible, chills it more or less, and changes the quality of the iron.

When the zone of fusion is pushed up on one side, as before described (see *Fig. 3*), a pocket is formed above and back of it, which catches a large volume of dust and disintegrated material. In the course of time, when the increasing heat happens to work up to the low point of the zone, and melting that part off, a heavy shower of dust is left down to the crucible. It is usual to increase

the burden when the furnace begins to work *hot*, but in this case it must be lowered to give to the crucible the heat required to work off the dust. These dust showers did not occur so frequently in the old furnace practice, as they used a much smaller crucible and volume of blast, which allowed the stock to build up on the bosh and lessen its reducing and disintegrating capacity. The ores were broken uniformly, and all fine ores screened out. There are thousands of tons of this fine ore at old furnaces, covered with vegetation, which will be used in the future with stronger blowing engines.

FIG. 3.

Fine ores reduce quickly and require rapid driving to prevent accumulation in the zone of fusion. Seven hours' exposure has been found sufficient to give No. 1 iron.

Higher up on the bosh large scaffolds form at times that come loose, slide down the crucible, exclude the fuel and chill the hearth. Damp weather will cool off a crucible, and if a heavy burden is carried, the barometer must be consulted and extra fuel charged in advance.

Using 10,000 feet of air per minute, a ton of coal per twenty-four hours is required to keep up the equilibrium of heat during a wet spell.

Since carrying heavier burden of ore and stone to a given weight of fuel has come into use, these dust troubles have increased and given rise to the expression, "too much burden"—which

implies loss of heat in the crucible to maintain the equilibrium in the zone of fusion. To an experienced founder, these dust troubles show beforehand, (1) by the gas; (2) by the pressure; (3) by the cinder; (4) by the iron; (5) by the charges driven in a given time and, knowing these with certainty, he can either warm up the crucible by higher heat of blast, or at once give the furnace a blank of fuel. Quick, prompt action in advance is required. With a hot crucible, the zone of fusion is shortened and the pressure is less. Heretofore, no attention has been paid to proportioning a furnace to use fine ore or an ore that disintegrates readily. Coarse, dense ores and fine ores should not be used together.

When a furnace begins to work colder, the back gas from the tuyeres shows white for a few seconds, when blast is thrown off, then black, and emits finely divided carbon in large volumes. As the furnace gets colder the quantity increases. This is accompanied by a higher pressure, and is due to disintegration of carbon.

Just here it will be well to call attention to the four filters or screens in the blast furnace.

(1.) The filter of cinder in the crucible, which allows the shots of falling iron to pass through it, and covering it carefully protects the iron from the oxidation of the blast;

(2.) The filter of fuel from the tuyeres to the zone of fusion, which takes up all oxygen of the air and carbonic acid, thereby preventing oxidation of the falling iron and any iron sponge passing the zone of fusion;

(3.) The zone of fusion acting as a filter allowing the fuel to pass through it as a solid, but liquefying the ore and stone. The pasty condition of the zone of fusion holds back the disintegrated stock, giving it time for reduction and fusion. If this pasty condition did not exist the fine ore would quickly rattle down through the stock to the crucible and floating on the cinder blanket, choke the crucible more or less. As part of the disintegrated ore would be reduced, it would quickly burn to oxide of iron and give red smoke at the chimney top, while the unreduced ore would melt, form finery cinder and pass out with the slag, causing a total loss of the fine ore; if any reduced ore passes through the slag, it changes the quality of the iron, as there is no carbon in it.

(4.) The dust and disintegrated material above the zone of fusion act as a screen or filter to intercept, to a great extent, the heat of

the ascending gas, and confine it to the zone of fusion below. That a certain amount of this fine material is required above the zone of fusion, is proven by the fact that on blowing in a furnace good work is not done until this accumulation takes place sufficiently to give a good working pressure. That also on shovelling out a healthy furnace that has been stopped by a break down, this material is found in great abundance about the top of the bosh.

The importance of the zone of fusion to the blast furnace and its laws are just being recognized. It must be maintained uniform if uniform iron is required, and must be kept as level as possible. It is extremely susceptible to any changes of heat below in the crucible.

This zone forms the dividing line between the reduction of the ores by carbonic oxides and the reduction by solid carbon. It might be called the digestive zone of the furnace.

Since rapid driving of furnaces has come into general use, it is found difficult to prevent the iron from melting through the crucibles, as they are much hotter from the larger volume of slag and iron falling into them. Cast-iron jackets, with water coil and thin walls, have been used, but the iron working through the cracks in the brickwork melted through the cast iron, and cutting down to the water coil caused explosions that burned the furnace men and destroyed the jacket.

The hearth also cuts down two to three feet, leaving the iron at a lower level. The iron trough is then lowered to get the iron. This is an error; it is better to let the iron lie in the bottom and let fresh iron accumulate on top of it to be drawn off at regular casting time, than to lower the hearth from time to time. At the end of the blast, the trough can be lowered, the iron drawn off, and a salamander in the hearth avoided. The iron tap hole, passing sixty to seventy tons of iron in fifteen minutes also gives way, burning the dam and sometimes cutting the coil, causing explosions that throw the molten metal in every direction. Watching a skilfully handled cast of sixty to seventy tons of iron, covering a space 30 x 100 feet, is a grand sight, but when this volume melts through the jacket, floods the building, explodes, scattering death among the furnace men, it is a different matter. Acts of heroism, surpassing those of the battlefield, have been performed by furnace men in trying to save their companions from such a terrible death.

In one case, forty-four tons worked out under ground into the cinder pit, when it commenced to boil, and drove the men out of the house. It was two hours before the men could approach the building, and it took forty-four hours to remove it and start the furnaces. The trouble to break up and remove the mass must be experienced to know its difficulty.

These boils are one of the curiosities of iron-making. A wet pig bed or a wet lump of clay as large as an acorn will start them, and if the iron is very hot they sputter and throw it all over the building. The peculiarity is that long after the moisture starting them is evaporated, the iron keeps up its molecular motion until it finally chills. Throwing water upwards in a fine spray and letting it fall on the metal chills the latter without an explosion.

The more recent improvements in connection with crucibles are as follows:

Heavy wrought-iron crucible jackets in sections extending from the trough of tuyere jacket down twenty-four inches below the hearth level, which is kept twelve inches above the ground Just below the hearth level and against the wrought-iron jacket is placed a six-inch pipe, making one coil around the jacket. One end of the coil is attached to the chimney of boilers and stoves, the other end terminates outside of the cast house, where it is attached to a small furnace. When the hearth is hot, cold air is drawn through this coil to chill the brickwork and prevent the iron melting through the jacket where it is buried underground and not exposed to the cooling influence of the air. When the crucible and hearth become cold, a fire is started in the furnace to warm them up and prevent loss from radiation and conduction. A hot crucible is the life of the furnace, and everything possible must be done to warm it up when it begins to lose its heat.

By taking it in time, serious trouble may be avoided. Laying the vertical courses with a space between them of pounded brick and clay, in connection with thicker walls and heavy jackets of wrought iron, prevents the melting through above the ground. This avoids all water connection below the tuyeres. The iron tapping hole six inches wide has on each side of it a false piece with water grooves in their backs, through which water trickles slowly to make moisture and chill the iron tap hole. An hour before cast-

ing, the water is turned off, and the moisture evaporates before casting. These false pieces are detachable, and readily replaced.

To avoid melting away the tap hole, it is stopped with clay, which melting, allows the iron to rush out in a large volume. Plumbago, in a cheap form, is now substituted, which resists the cutting action of the flow of iron. To bot up an iron tapping hole requires skill, and must be done quickly to get blast on the furnace with as little loss of time as possible. It must be well stopped back, and the plumbago worked out to the front edge of the false pieces, leaving an opening of say two and one-half inches in diameter, about half the depth of the stopping. This holds the iron in check, and saves the false pieces. The latest improvement is an air-cooled iron notch stopped with a hollow plumbago stopper. The stopper is filled with sand, which can be picked out quickly and a bar driven through the end of the stopper lets out the metal. The iron running through the hollow stopper wears it away, making place for another. This avoids the old stoppage and botting up. In connection with it is an automatic skimmer, which requires no watching or handling by the furnace men. The tuyeres are now inserted in the tuyere breasts with a metallic joint, and the tuyere breasts are secured to the tuyere jacket which holds them up to their work, even when all the brickwork inside the tuyere jacket is melted away.

Tuyere nozzles have been improved by making them of bronze and fitting them, metal and metal, to the tuyere nose, which prevents them from burning and allows them to be placed nearer the nose of the tuyere, thereby avoiding expansion of blast in the end of the tuyere. Nozzles with spiral grooves giving a twisting motion to the blast, are used when a strong penetration is required. These cause the blast to work further in by pushing the pieces of fuel apart. To detect quickly when blast is not entering all the tuyeres alike, a differential gauge is used, one to each tuyere pipe. To the circular blast pipe an inch pipe is attached, leading to the side wall of the cast house, where the gauges are placed and on one side of each is attached this inch pipe. In the connection of the tuyere pipe to the circular pipe is placed a reducer or bushing, sufficient to give a half pound back pressure or friction in the passing blast, and which serves to distribute the

blast at each tuyere more evenly. From each tuyere pipe connection, just below the reducer, is run a three-eighths-inch pipe and attached to the other side of the gauges. Mercury is placed in the tubes to half the height of the glass, the blast is then turned on. If blast is entering a tuyere rapidly, one column of mercury rises, the other falls, and if no blast enters the tuyere, both columns remain at the same height, as, the blast in the tuyere pipe being stationary, shows the same pressure in the blast as in the circular pipe. A simple inspection at any moment shows what each tuyere is doing, and whether the blast is working up one side of the furnace or evenly at all the tuyeres. When a gauge shows a tuyere is not taking blast, the furnace man must open it at once with the pricker rod and see that it gets its share of blast. The tuyeres are the life of the furnace and they must be kept free and open In the old practice, the bright tuyere was considered the best, but these gauges have proved the reverse, as the bright tuyere using but little blast makes an intense local combustion and glowing fire at the nose of the tuyere, but there is no penetration. Running a pricker rod through this glowing surface, the hard, cold fuel is found back of it.

Cinder notches (now universally used) are made in three parts, arranged to take apart readily, and when the furnace makes cinder rapidly enough, a continuous flow is used which, running at a moderate speed, does not destroy the notch, trough, or cinder cars. Opinions vary on this, but in time the continuous flow will be universal, even if a second cinder notch with larger opening is required to blow a flush from. The old practice of running by pressure of blast is now done away with, and running by revolutions of engine practiced. The volume of blast blown into the crucible, and not the pressure determines the volume of iron to be made. Care must be used with a crucible that has lost part of its heat as sufficient blast only to maintain combustion must be used, and as the fire gets hotter the volume can be increased. If too much is blown, the fire is blown out and the crucible chills. Patience and firmness will master the trouble.

The products of the crucible are:

The gases, the slag, and the iron. The gases are carbonic acid, carbonic oxide, nitrogen, the cyanides, and hydrogen, the two

latter being in small quantities. The constituents of the slag vary between the following limits:

Silica,	20 to 72 per cent.
Lime,	0 to 60 "
Magnesia,	0 to 34 "
Alumina,	0 to 30 "
Protoxide of manganese,	0 to 34 "

A slag making No. 1 iron from good stock runs silica 40, lime 25, magnesia 18, alumina and iron 17. In color, they vary from the creamy white or gray, No. 1 iron, to the glossy black from No. 5, with all intermediate shades. Dark green shows protoxide of iron present, in small quantities; light green shows protoxide of manganese; black shows large quantities of protoxide of iron and a heavy slag with a dull metallic lustre; reddish-gray black shows unreduced ores are melting and the furnace working raw. This alarms a furnace man more than any other trouble. When a scaffold is working off from the bosh wall a scaly reddish brown puffy cinder is formed. As a rule, a limpid cinder with white to gray fracture gives No. 1 or 2 iron if there is but little sulphur or manganese present. In working some ores, there is a curious exception; the last flush before casting must be a rough, dark slag to give No. 1 iron. With a limpid slag, the shots of iron pass quickly through it and are buried beyond the reach of the oxidation or decarbonization of the blast. A furnace at times will make two different slags, as one part of the crucible may be working off a piece of scaffold, or working cold, while the other part is working hot.

Where slag runs out and cools in runners, the out end on cooling pushes up in convex surfaces called bull's eyes, which, if they cool glassy on surface indicate want of lime.

The same test can be made by taking samples in cups, cooling them and breaking them when the fracture will show by any glassiness the want of lime. The quality of the iron being made at the time must be taken into consideration with the glassiness of the slag. Each furnace man must, by comparative tests, establish his guides, which old founders did well with before the days of analyses.

The tests used to determine whether there is lime enough in the slag, are (1), catching a small amount on a rod and drawing it out

in threads, which, if they snap off brittle, indicate lime enough; but if they are elastic, indicate that more lime is wanted; (2), by coating a rod, say one-sixteenth of an inch thick, letting it cool and examining its brittleness. Heat bleaches slag, and founders are often deceived in thinking a light-colored cinder is too limy. Crushing a cinder to powder and examining its color will show if unreduced oxide is present by its dark color. In building up the heat in the crucible, the cinder shows by its fluidity and color how it is progressing, and the first sign of a gray coating is watched for anxiously.

The slag shows alternate layers of black and white during this time. When too much lime is used, it can be quickly corrected by some quartz sand charged with the stock which soon works down to the zone of fusion. Samples of cinder taken from each flush and placed side by side during a shift, give a continuous history of the shift.

A slag that will run fluid and on cooling go to powder is of the following composition: Silica, 36·2; alumina, 11·0; lime, 48; magnesia, 1·4; calcium sulphide, 2·5; oxide manganese, ·5.

When sulphur is present in fuel or ore, the cinder must be basic to take up the sulphur. With rich ores containing sulphur, the cinder must be extra basic, as its small volume soon becomes acid in washing the sulphur out of the iron. This rule must be observed also with pure rich ores and sulphurous coke.

The flow of the slag, its limpidity and color are carefully watched by a good furnace man, as it gives with sound judgment a quick index to the interior workings of the furnace. Acid slags take less fuel, but give poorer iron and more of it. Basic slags take more fuel, give better iron, but less of it to a unit of fuel.

The third product of the crucible, iron, varies from No. 1, a black large open grain with sharp-pointed facets scratching the fingers, to No. 5, or iron with no facets. Nos. 1, 2, 3 are gray; No. 4 mottled or white, with gray spots, and No. 5 white. No. 1 iron is from a hot furnace, but if it works too hot the iron before spoken of is made, containing five to seven per cent. of silicon, soft, white, weak fluid (runs like water), and fit only for artistic work or light castings, requiring no strength. Carbon is what gives cast iron its strength and value, the other elements change its character for strength and weakness to a limited extent.

For a general rule, the sum total of the graphitic carbon and combined carbon is the same in all grades, but there is little graphitic carbon in No. 5, being nearly or all combined carbon, which is the cause of its extreme hardness and density. No 1 is high in graphitic carbon with little combined carbon, which is the cause of its softness and black color. With intense heat in a cupola and plenty of fuel white iron can be made kishy or gray.

One of the best brands of No. 1 foundry iron in the market runs: Iron, 93·40 per cent; graphitic carbon, 3·12; combined carbon, ·40; silicon, 2·43; phosphorus, ·34; sulphur, ·020; manganese, ·24.

No. 5 iron usually contains ninety-five per cent. iron with about 3·2 per cent. carbon, nearly all combined.

Much can be judged of the quality of iron as it flows from the furnace. Exceptions occur in their fluidity by the crucible cooling it after it is made, as at times No. 1 has been found to flow sluggish and thick. The local causes for changes must be studied carefully by the furnace man, or he is at a loss to account for things taking place, and changes burden or heat in blast, when it would be better to leave it alone. Like the skilful doctor, the founder must study his dumb patient.

DOWNWARD-DRAUGHT FURNACES.

CARLOS A. LOZANO and H. F. T. ERBEN.

(*Concluded from vol. cxxiv, page 388.*)

C. G. S. thermal units per gramme of the coal, 7,607 C. G. S. thermal units per gramme of dry coal, 8,475 C. G. S thermal units per gramme of combustible, 15,255 British thermal units per pound of combustible, the composition of the coal as fed during the two test being respectively—

	Before Change.	*With the Post and Sawyer Attachment.*
Carbon,	·8387	·8417
Hydrogen,	·0150	·0150
Sulphur,	·0093	·0093
Liquid water,	·0385	·0355
Ash,	·0985	·0985
	1·0000	1·0000

whence, the composition of the coal as disposed of by the furnace, was respectively—

	Before Change.	*With the Post and Sawyer Attachment.*
Carbon,	·80251	·77101
Hydrogen,	·01500	·01500
Sulphur,	·00930	·00930
Liquid water,	·03850	·03550
Ash + unburned coal,	·13469	·16919
	1·00000	1·00000

whence the composition of a pound of combustible burned during each test—

	Before Change.	*With the Post and Sawyer Attachment.*
Carbon,	·971	·969
Hydrogen,	·018	·019
Sulphur,	·011	·012
	1·000	1·000

each pound of combustible burned carrying along with it respectively—

	Before Change.	*With the Post and Sawyer Attachment.*
Ash + unburned coal, (·119 ·191 ·044 ·069)	·163	·213
Liquid water,	·047	·045

the calorific power of such combustible as was burned in each case being per pound of combustible burned—

	Before Change.	*With the Post and Sawyer Attachment.*
·971 × 14500 =	14080	
·018 × 62032 =	1117	
·011 × 3996 =	44	
·969 × 14500 =		14051
·019 × 62032 =		1179
·012 × 3996 =		48
British thermal units,	15241	15278

if completely peroxidized.

CHIMNEY GASES.

We took three samples of the chimney gases in each test, one just after slicing and firing, one just before firing, one midway between two firings, collecting them by means of a large aspirator and then transferring them under water to glass bottles provided with good stoppers and kept bottom up under water.

For the analysis we used Elliott's apparatus, and as reagents the following solutions—

K O H, 1 in 20 parts of water, for CO_2.

Br, for illuminants.

K O H, 1 in 20 parts of water, with 3 per cent. pyrogallic acid, *i. e.*, potassic pyrogallate, for O.

$Cu_2 Cl_2$, 1 in 4 parts of strong H Cl, for CO,

the analysis being necessarily incomplete for want of the additional apparatus for the estimation of the H and C H_4, or facilities for otherwise analyzing the residue of the gases; quite sufficient, though, for the purposes of the investigation.

The analysis was performed in a cool room, at nearly constant temperature, with water and chemicals at the temperature of the room. No traces of illuminants were found in any of the samples.

The results of the analyses are per unit volume—

(I.) Sample taken just after slicing and firing—

	Before Change.	*With the Post and Sawyer Attachment.*
CO_2,	·087	·064
O,	·075	·084
CO,	·010	·012
N + etc.,	·828	·840
	1·000	1·000

(II.) Sample taken just before firing—

CO_2,	·083	·074
O,	·094	·074
CO,	·000	·029
N + etc.,	·823	·823
	1·000	1·000

(III.) Sample taken midway between two firings—

CO_2,	·086	·070
O,	.095	.105
CO,	.000	·010
N + etc.,	·819	·815
	1·000	1·000

For the reduction to parts by weight we used the following—

Density of H =	1·
CO_2 =	21·94
O =	15·96
CO =	13·96
N =	14·01

Theorizing on the composition of the item N + etc., we got figures which check very well with the above given, thus testing the correctness of the above results.

Multiplying together the volumes and densities, we get—

SAMPLE I, BEFORE CHANGE.

CO_2 = 1·90878	containing O = 1·38820	+ C =	·52058
O = 1·19700	containing O = 1·19700	+ C	
CO = ·13960	containing O = ·07977	+ C =	·05983
3·24538		2·66497	·58041

$$\frac{O}{C} = 4{\cdot}592.$$

SAMPLE I, WITH THE POST AND SAWYER ATTACHMENT.

CO_2 = 1·40416	containing O = 1·02121	+ C =	·38295
O = 1·34064	containing O = 1·34064		
CO = ·16752	containing O = ·09573	+ C =	·07179
2·91232	2·45758		·45474

$$\frac{O}{C} = 5{\cdot}404.$$

SAMPLE II, BEFORE CHANGE.

CO_2 = 1·82102	containing O = 1·32438	+ C =	·49664
O = 1·50024	containing O = 1·50024		
CO = 0·00000	containing O = 0·00000	+ C =	·00000
3·32126	2·82462		·49664

$$\frac{O}{C} = 5{\cdot}687.$$

SAMPLE II, WITH THE POST AND SAWYER ATTACHMENT.

CO_2 = 1·62356	containing O = 1·18077	+ C =	·44279
O = 1·18104	containing O = 1·18104		
CO = ·40484	containing O = ·23134	+ C =	·17350
3·20944	2·59315		·61629

$$\frac{O}{C} = 4{\cdot}208.$$

SAMPLE III.—BEFORE CHANGE.

CO_2 = 1·88684	containing O = 1·37225	+ C =	·51459
O = 1·51620	containing O = 1·51620		
CO = 0·00000	containing O = 0·00000		
3·40304	2·88845		·51459

$$\frac{O}{C} = 5{\cdot}613.$$

SAMPLE III.—WITH THE POST AND SAWYER ATTACHMENT.

CO_2 = 1·53580	containing O = 1·11695	+ C =	·41885
O = 1·67580	containing O = 1·67580		
CO = ·13960	containing O = ·07977	+ C =	·05983
3·35120	2·87252		·47868

$$\frac{O}{C} = 6{\cdot}001.$$

MEAN SUPPLY OF AIR.

Assuming that sample (1.) of the chimney gases represents average sample during five minutes after each firing, and that each of the others is average sample during one-half of the rest of the time, we find the mean $\frac{O}{C}$ in the gases. Thus,

	Before Change.	*With the Post and Sawyer Attachment.*
Mean $\frac{O}{C} = \frac{4{\cdot}592 \times 115 + (5{\cdot}687 + 5{\cdot}613)\ 422{\cdot}5}{960}$ =	5·523	
Mean $\frac{O}{C} = \frac{5{\cdot}404 \times 145 + (4{\cdot}208 + 6{\cdot}001)\ 416}{977}$ =		5·148
Multiplying these by the quantities of carbon in the combustible burned—		
$\frac{O}{\text{Combustible}}$ = ·971 × 5·523 = ...	5·363	
$\frac{O}{\text{Combustible}}$ = ·969 × 5·148 = ...		4·989
Adding to which the oxygen needed to burn the hydrogen in the one pound of combustible—		
·018 × 8 = ...	·144	
·019 × 8 = ...		·152
And the oxygen needed to burn the sulphur in the one pound of combustible—		
·011 × 1 = ...	·011	
·012 × 1 = ...		·012
The sum is the		
Total mean $\frac{O}{\text{Combustible}}$ = ...	5·518	5·153
$\frac{100}{23}$ of which is the		
Total mean $\frac{\text{Dry air}}{\text{Combustible}}$ = ...	23·98	22·40
whence,		
Total mean $\frac{\text{Dry air}}{\text{Dry coal}}$ = ...	20·61	18·48
and		
Total mean $\frac{\text{Dry air}}{\text{Coal as fed}}$ = ...	19·82	17·81

HUMIDITY OF THE AIR.

From the observations of the temperatures by dry bulb and wet bulb thermometers, and by Table VII, of the hygrometrical tables by Arnold Guiot for the Smithsonian Institution, we find that the mean pressure of water vapor in the air in the boiler room during the tests was—

	Before Change.	*With the Post and Sawyer Attachment.*
P = in inches of mercury, at 32° F., . . .	1·4901	1·658
And as the mean barometrical reading reduced to 32° F., was	30·05	29·839
The pressure due to dry air was	28·560	28·181

The weight of a cubic foot of dry air, at 32° F., under the pressure of 29·922 inches of mercury is ·080728 pound. The weight of a cubic foot of steam gas, temperature and pressure the same, is ·622 × ·080728 pound. For the given variations of pressure and temperature both air and vapor may be assumed to behave as perfect gases, when, following Balfour-Stewart's reasoning, Art. 158 of his *Treatise on Heat*, the weight of dry air in a cubic foot of the atmospheric mixture was, during the first test—

$$W_a = \cdot 080728 \times \frac{28\cdot560}{29\cdot922} \times \frac{1}{1 + (110\cdot6 - 32)\frac{\cdot365}{180}}$$

and the weight of vapor of water in the same cubic foot,

$$W_w = \cdot 622 \times \cdot 080728 \times \frac{1\cdot49}{29\cdot922} \times \frac{1}{1 + (110\cdot6 - 32)\frac{\cdot365}{180}}$$

whence the weight of water vapor per unit weight of dry air in the mixture is—

$$\frac{W_w}{W_a} = \cdot 622 \times \frac{1\cdot49}{28\cdot56} = \cdot 03245$$

and similarly, by substitution of the corresponding figures, for the second test, whence,

	Before Change.	*With the Post and Sawyer Attachment*
$\frac{W_w}{W_a}$ = ...	·03245	·03659

The specific heat of dry air being ·238 and that of steam gas ·475, it follows that the mean specific heat of the atmospheric mixture during the experiments was—

	Before Change.	*With the Post and Sawyer Attachment.*
Specific heat of atmospheric mixture, . . .	·24545	·24636

MEAN LOSS OF HEAT BY FORMATION OF CO.

From the weights given in pages 425, 426, we may, by means of the assumption used in computing the mean supply of air, calculate the carbon which underwent partial oxidation, thus—

	Before Change.	*With the Post and Sawyer Attachment.*
$\frac{\frac{\cdot 05983}{\cdot 58041} \times 115}{960} \times 971 =$	·012	
$\frac{\frac{\cdot 07179}{\cdot 45474} \times 145 + \left(\frac{\cdot 05983}{\cdot 47868} + \frac{\cdot 17350}{\cdot 61629}\right) 416}{977} \times \cdot 969 =$		·19

are respectively the fractions of a pound of carbon oxidized to CO per pound of combustible during each test.

Multiplying these by 10,100, we get the mean loss of heat per pound of combustible in each trial, owing to CO, respectively

	Before Change.	*With the Post and Sawyer Attachment.*
British thermal units, ...	121	1919

Thus by means of the actual imperfection of the combustion in the furnace, the mean calorific power was reduced—

	Before Change.	*With the Post and Sawyer Attachment.*
from the British thermal units (see page 424),	15241	15278
to the actual heat obtainable under the circumstances, British thermal units, . . .	15120	13359

per pound of combustible burned.

CALORIFIC INTENSITY.

From the composition of a pound of combustible (page 423), and from the figures given above, we calculated the products of combustion as follows—

BEFORE CHANGE.

	Pounds.	*Oxygen Thus Taken Up.*
$CO = \cdot012\ (\frac{4}{3} + 1)$, ... =	·028	·016
$CO_2 = \cdot959\ (\frac{8}{3} + 1)$, ... =	3·516	2·557
$H_2O = \cdot018\ (8 + 1)$, ... =	·162	·144
$SO_2 = \cdot011\ (1 + 1)$, ... =	·022	·011
1·000		2·728

and the accompanying moisture and ash,

H_2O, ... =	·047
Ash, ... =	·163

The 23·98 pounds of dry air supplied per pound of combustible carried along 23·98 × ·03245 pound vapor of water, whence H_2O, ... = ·778

Besides this we have the nitrogen that went in with the oxygen used in chemical combination, and the air of dilution—

$N = \frac{77}{23} \times 2·728$, ... =	9·132
$Air = 23·98 - \frac{100}{23} \times 2·728$, ... =	12·120
Total, ...	25·968

per pound of combustible burned.

Similarly

WITH THE POST AND SAWYER ATTACHMENT.

	Pounds.	*Oxygen Thus Taken Up.*
$CO = \cdot19\ (\frac{4}{3} + 1)$, ... =	·443	·253
$CO_2 = \cdot779\ (\frac{8}{3} + 1)$, ... =	2·856	2·077
$H_2O = \cdot019\ (8 + 1)$, ... =	·171	·152
$SO_2 = \cdot012\ (1 + 1)$, ... =	·024	·012
1·000		2·494

and the accompanying moisture and ash,

H_2O, ... =	·045
Ash, ... =	·213

The 22·4 pounds of dry air supplied per pound of combustible carried along 22·4 × ·03659 pound vapor of water, whence H_2O, ... = ·820

Besides this, we have the nitrogen that went in with the oxygen used in chemical combination, and the air of dilution—

$N = \frac{77}{23} \times 2·494$, ... =	8·349
$Air = 22·4 - \frac{100}{23} \times 2·494$, ... =	11·557
Total, ...	24·478

per pound of combustible burned.

According to these computations, the supply of air per pound of combustible burned was—

	Before Change.	*With the Post and Sawyer Attachment.*
For combustion,	11·860	10·843
For dilution,	12·120	11·557

The following is the computation of the mean specific heat of the products of combustion and necessary adjuncts which share the heat evolved by a pound of the combustible.

BEFORE CHANGE.

	Weights.	*Specific Heats.*	*Products.*
CO,	·028	·245	·007
CO_2,	3·516	·217	·763
H_2O,	·162	·475	·469
H_2O,	·047		
H_2O,	·778		
SO_2,	·022	·155	·003
Ash,	·163	·200	.033
N,	9·132	·245	2·237
Air,	12·120	·238	2·885
	25·968		6·397

$$\frac{6·397}{25·968} = ·246 = \text{mean specific heat required.}$$

WITH THE POST AND SAWYER ATTACHMENT.

	Weights.	*Specific Heats.*	*Products.*
CO,	·443	·245	·109
CO_2,	2·856	·217	·620
H_2O,	·171	·475	·492
H_2O,	·045		
H_2O,	·820		
SO_2,	·024	·155	·004
Ash,	·213	·200	·043
N,	8·349	·245	2·046
Air,	11·557	·238	2·750
	24·478		6·064

$$\frac{6·064}{24·478} = ·248 = \text{mean specific heat required.}$$

In both cases, if we followed the rather usual practice of taking the mean specific heat of the products of combustion and adjuncts as equal to the specific heat of air, the difference would be considerable.

As above seen, the number of heat units per degree of rise of temperature in the furnace, or, as often called, the water equivalent of the products of combustion and adjuncts, is for a pound of the combustible in each case.

	Before Change.	*With the Post and Sawyer Attachment.*
	6·397	6·064
From the British thermal units, mean heat evolved per pound of combustion burned (see page 429), ...	15120	13359
We deduct the latent heat of evaporation of the H_2O of chemical combustion and of the moisture in the coal (·162 + ·047) 966·1 =	202	
(·171 + ·045) 966·1 =		209
Leaving British thermal units, mean available heat.	14918	13150

The mean temperature of the products of combustion during the trials (the mean external temperatures having been respectively 65° and 78° F.), was in each trial nearly—

	Before Change.	*With the Post and Sawyer Attachment.*
$65 + \frac{14918}{6·397} =$	2397°	
$78 + \frac{13150}{6·064} =$		2247°

When with the same supply of air all the carbon is peroxidized, the mean temperature becomes a trifle higher than the above higher temperature. If the coal could be burned without dilution, however, the mean temperature would rise above 4,000° F., and 4 or 5 times as high if the nitrogen and moisture could be kept off. A piece of cast iron placed in the hottest of the fire during the test before the change, actually melted down, and if its fusing point was not lower than that given by Bloxam's work on *Metals*, published by Appleton, in 1882, viz., 2,780° F., it may be an additional evidence of the fact that the intensity of the heat on the burning coals and the mean heat of all the products of combustion are two different things.

SUMMING UP.

	Before Change.	*With the Post and Sawyer Attachment.*
Total heat of combustion of 1 pound of combustible burned + the carbon with it, which escaped unburned, British thermal units, .	15879	16569
Latent heat of evaporation of the H_2O of combination and of the moisture in the coal, per pound of combustible burned, British thermal units, ...	202	209
Available heat of 1 pound of combustible + the carbon with it, which escaped unburned, if the combustion had been complete and perfect, British thermal units, ...	15677	16360
Heat equivalent of the unburned carbon in the ashes of 1 pound combustible burned, British thermal units, ...	638	1291
Heat which failed to be generated, owing to the formation of CO, British thermal units, per pound of combustible burned, . . .	121	1919
Mean available heat obtained, British thermal units, per pound of combustible burned, .	14918	13150
Mean heat imparted to the steam made, British thermal units, per pound of combustible (see p. 383), ...	10813	10334
Considering the efficiency of the boiler complete in its two parts, the efficiency of generation and that of transmission of heat, we have—		
Efficiency of generation— $\frac{14,918}{15,677}$ and $\frac{13,150}{16,360}$	·952	·804
Efficiency of transmission— $\frac{10,813}{14,918}$ and $\frac{10,334}{13,150}$	·725	·786
The efficiency of the boiler being the product of the two, ...	·690	·632
The temperature corresponding to the pressure of the steam generated was by formula, p. 237 of Rankine's S. E., ...	298°·7	298°·6
The mean of the observed temperature of the flue gases was, ...	340°·	293°·

Of course, these figures being simply the means calculated from the hourly observations, are not such accurate means as might be obtained by the use of instruments automatically recording the pressures and temperatures by continuous curves; but they cannot be very far wrong, and it appears safe to infer from them—

(1.) That the boiler before the change had all the heating surface that could do it good under the other existing circumstances.

(2.) That after the change, it had too much heating surface.

The per cent. of increase of heating surface with the Post and Sawyer attachment was 10·8. The per cent. of increase of efficiency of transmission was 8·4.

The claim of "complete combustion" was completely disproved, the losses by unburned carbon and by production of CO being greater than with the ordinary grate and draught, while the rate of combustion per hour per square foot of grate was practically the same in both cases.

A comparison of the quantities of CO and $\frac{C}{O}$ in the products of combustion, pages 425-426, shows that there is no hope of reducing the quantity of the air of dilution by means of the Post and Sawyer device.

A mere inspection of the dimensions compared, page 377, and results of the tests and calculations, pages 383 and 433–434, will show at once, that, whereas the efficiency of transmission of the heat generated was increased, which we should expect from the considerable increase of heating surface, the Post and Sawyer attachment was fairly beaten in all other possible ways, and that its attachment to the boiler was, in this case, disadvantageous.

It may, however, be an improvement, in some respects, if attached to a boiler which greatly needed an increase of heating surface.

FORBES'S ELECTRIC METERS.

By Prof. Edwin J. Houston.

The necessity for some reliable apparatus for automatically registering the total quantity of electricity supplied to any consumer is well recognized. The rapid growth that has recently taken place in the United States in systems of electric distribution by means of alternating currents, has brought before electricians the necessity for some reliable device for measuring and automatically recording the passage of such currents.

There are in general three effects of an electric current, that may be utilized for the operation of an electric meter, viz., the chemical, the magnetic, and the heating effects.

In a system of alternating currents, the chemical effects are practically absent and cannot therefore be utilized. The magnetic effects have been employed for the operation of alternating current meters, with some little success, but these instruments have not proved as reliable as is desired, since, as generally constructed, their indications depend not alone on the volume of the current that is passing, but also on the number of alternations per second.

The third effect of an electric current, viz., the heating effect, has been happily applied by Prof. Geo. Forbes,* of London, to the operation of a current meter, suitable alike for the measurement of direct and of alternating currents. These current meters, when applied to registering the consumption of electricity for constant currents, possess the advantage over instruments depending for their operation on the chemical decomposition of electrolytes, since they readily permit the passage of the entire current through the measuring apparatus, and thus entirely avoid the very great disadvantages of shunts and variations that necessarily occur in the internal resistance of the decomposing cell.

Prof. Forbes, in his current meter, causes the convection currents, produced by the heating of any fluid substance by means of a coil

* See elsewhere in this impression of the Journal, a paper by Prof. Geo. Forbes, "On an Electric Current Meter."

of wire traversed by the current to be measured, to move a spiral or wheel, and automatically to record the number of such rotations by the use of suitable mechanism.

The following description of his electric meters is taken mainly from his United States letters-patent, No. 366,824, "For apparatus for measuring electricity," granted July 19, 1887.

The general principles of the invention is thus clearly stated by the inventor in the specification of the above-mentioned letters-patent, viz:

"My method of measuring electric currents is founded upon the fact that an electric current passing through a conductor of electricity generates heat, which heat is carried away from the conductor by the air in contact with it, thus forming convection currents in the air. The velocities of these air currents are proportional to the strength of electric current in the conductor. I measure the strength of electric current by introducing any kind of apparatus suitable for measuring the velocity of air currents. I do not confine myself to the use of atmospheric air. I sometimes use hydrogen or other gases, and sometimes I employ liquids."

As is well known, the heat generated by an electric current flowing through any coil of wire is equal to the product of the square of the current strength that passes through the coil of wire into the resistance of the coil. The heat generated by the electric current creates a motive-force that tends to cause or set up air currents. These air currents will acquire a uniform velocity as soon as the resistance caused by the fluid friction of the air produces an opposing force equal to the motive-force of the heat. Any variation in the amount of the fluid resistance will cause a variation in the velocity of the air currents. In order to obtain high velocity with a small current strength, it is only necessary to decrease the fluid resistance as much as possible. This is accomplished by the inventor by placing the coil of wire, in which the heat is produced, an inch or two above the base of the apparatus. By this expedient the air is subjected to less resistance in passing over the base to reach the conductor.

To ensure uniformity in the velocity of the air currents, as well as to protect the moving mechanism from the influence of extraneous currents, a glass, or other suitable shade, is placed over the apparatus. In some cases the heated air currents are directed

toward the registering apparatus by means of a glass cylinder placed inside the shade immediately above the heating wire coil.

The heating coil is made of a flat coil of ordinary wire, or from strips of metal. The generation of heat at the places where the current passes into and out of the coil, is avoided by increasing the cross-sections of the junctions, and so reducing their resistance. This also has the effect of concentrating the heat on the space occupied by the coil proper.

In some of his later forms of instruments, the inventor employs coils of iron wire. Such coils are liable to injury from rusting, thus varying their resistance. This, however, may be avoided by filling the space inside the glass shade with nitrogen or other gas inert to the metal.

Prof. Forbes has applied the principles of his invention to the case of apparatus suitable for the following purposes, viz:

(1.) For measuring current strength.

(2.) For automatically registering the total quantity of current passing through devices placed in parallel on constant potential mains, for both large and small ranges of current.

(3.) For automatically registering the total quantity of current passing through devices placed in a constant current circuit, *i. e.*, suitable to a system of series distribution for both large and small ranges of current.

The following are among some of the more important of the apparatus described in the specifications of the United States letters-patent already alluded to.

In *Fig. 1* is shown an apparatus designed to measure current strength. It consists, as shown, of a spiral *F*, of paper, cut from a disc and suspended by a silver wire *E*, or by a bifilar suspension, directly above the metal ring *H*, that is heated by the passage of the current. A glass cylinder *S*, supported on the columns *B*, *B*, *B*, is provided for directing the air currents on the paper spiral. A glass shade, *C*, *C*, resting on the wooden base *A*, encloses the entire apparatus and shields the paper spiral from the influence of extraneous currents of air. A clip *D*, on top the glass shade, holds the wire *F*. A pointer *I*, supported by the wire, moves over the graduated dial *M*. The binding posts *K*, *K*, serve to pass the current to be measured through the conductor *H*.

With this apparatus, the spiral will be turned through an angle that is proportional to the square of the electric current.

Instead of the paper spiral, the apparatus shown in *Fig. 2* may be used. In this form a cork A^1, is fitted with four vanes of mica, B^1, B^1, inclined at angles of 45° to the vertical. A glass rod C^1, C^1, passes through the centre of the cork, and bears at its upper end

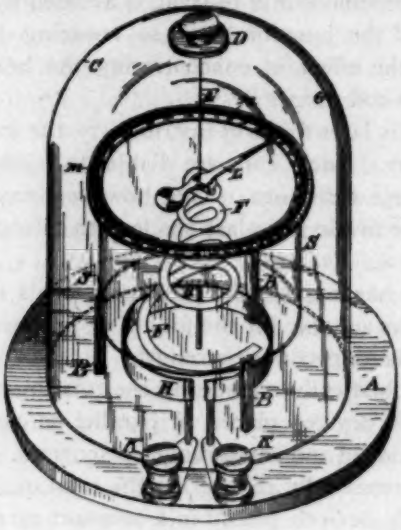


FIG. 1.

the supporting wire D^1, of silver. The pointer E^1, is fixed to the glass rod C^1, in the position shown.

The form of apparatus for measuring the current strength, preferred by the inventor, is shown in *Fig. 3*. Here the portion

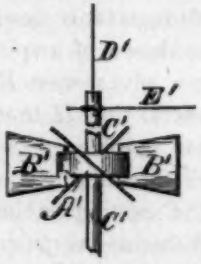


FIG. 2.

rotated by the current is represented by a disc of mica H^2, with the corks fixed at equal distances from each other on its edge. Each of these corks is furnished with a mica vane L^2, inclined at an angle of 45°. This apparatus is supported, as shown, by the fine

silver wire A^2. C^2, is a rod carrying the pointer D^2, which moves on the graduated circle E^2, E^2, in the base of the instrument. The metallic conductor F^2, F^2, which isheated by the current, consists of a circular strip of metal slit at one place, and connected to the binding posts G^2, G^2. An enclosing cylinder of glass is placed as shown.

The graduated circle E^2, E^2, is sometimes divided, "so that the pointer will indicate the current directly, or it may conveniently be divided into 100 parts, so that a deflection of more than one revolution may be noted, a table of values being in this case provided

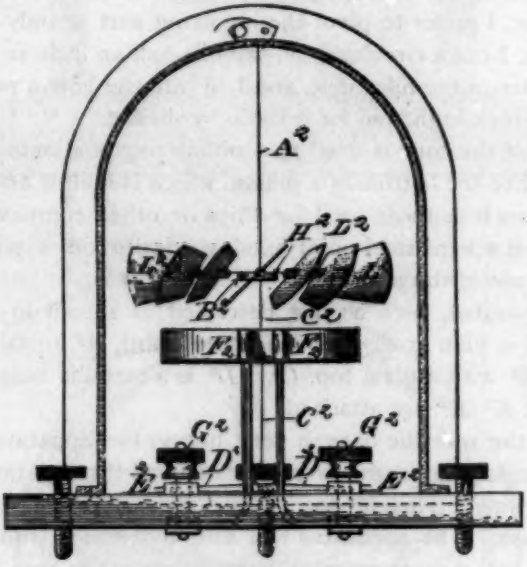


FIG. 3.

for converting the readings into values of the electric current. When it is required to measure very small currents, the conductor may have a high resistance, and may be made of wire wound in many turns."

The high resistance required for this purpose may be obtained, if so desired, by employing in the place of the metallic wire, a string rubbed with powdered plumbago. When any high resistance conductor is used, the instrument may be employed for measuring differences of electric potential.

The inventor thus describes his coloumbmeter, viz.:

"When I wish to measure the total quantity of electricity which has passed through the conductor in any time, I sometimes mount the revolving part upon a delicate spindle, pivoted at the two ends and carrying a pinion or wheel, which gears into wheel work of such proportions as to give convenient means of reading off the number of revolutions of the vanes, as in anemometers, gas meters, etc. The number of revolutions so read off is a measure of the total quantity of electricity which has passed through the conductor. I prefer, however, to use the mica disc and vanes described above, without any enclosing cylinder to direct the air current. In this case, I prefer to pivot the revolving part at only one point. To do this, I cut a circular hole, say one-half an inch in diameter, in the centre of the mica disc, and I fit into the hole a paper cone, about one inch high, and fix it there by shellac." * * * * *

"The top of the cone is fixed to a minute ring of aluminium, which is attached to the bottom of a pinion, which is hollow and carries a ruby cup, such as those used for ships or other compasses. This cup rests on a hard steel point fixed vertically on a pillar rising from the base of the apparatus."

An apparatus, such as just described, is shown in section in *Fig. 4* and in plan in *Fig. 5*. The base board, A^3, sustains a brass cylinder, B^3, with a glass top, C^3. D^3, is a metallic base, to which the pillars, E^2, E^2, are attached.

When the metallic base is very heavy, the apparatus will not begin to register until the current has passed through the wire coil for some time. This is due to the absorption of heat by the metallic base. The apparatus will also continue to run for some time after the current ceases. In later forms, the base is made of slate.

The paper cone is shown at e^3, the pinion f^3, at its apex contains a ruby cup which rests on a supporting steel point. The circular disc of mica b^3, has the corks c^3, c^3, with mica vanes d^3, d^3, attached thereto as shown. Any suitable arrangement of wheels and pinions may be employed in connection with the apparatus.

The conductor q^3, may be made of platinum, silver-alloy or other suitable alloy, and is in connection with the binding posts as shown.

"When this apparatus is used as an electric meter in a distribution on the parallel system at constant potential, if there were no

friction in the solid parts of the apparatus, it would act with absolute truth; but besides the air friction, which varies as the square

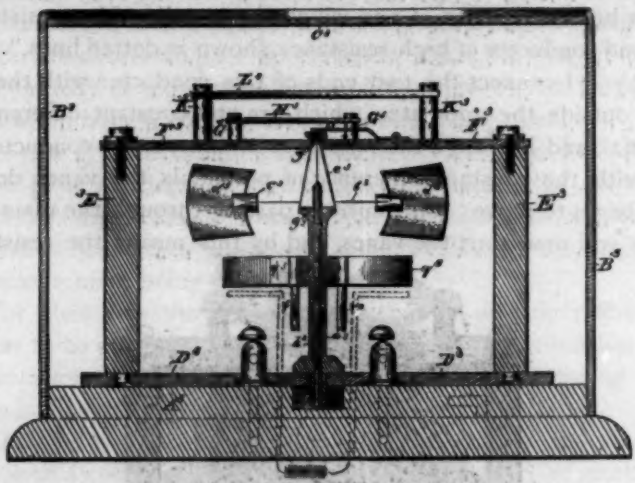


FIG. 4.

of the velocity of the air current, we have the constant friction of the pivot and wheel gearing. This is unimportant when the range

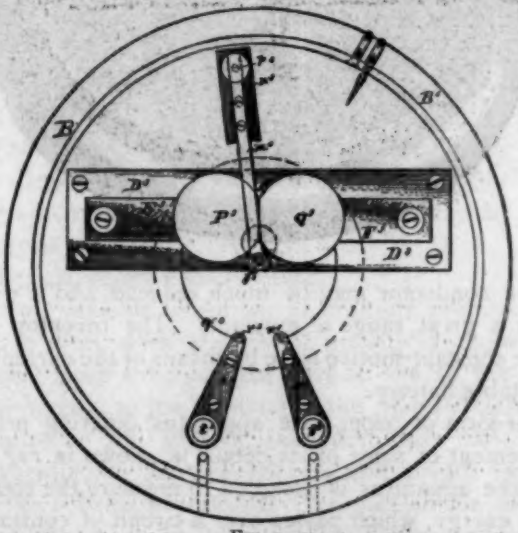


FIG. 5.

of currents to be measured is not large. When this range is large, I introduce a constant source of heat nearly sufficient to overcome

the constant friction, and nearly sufficient to start the apparatus. To obtain this constant source of heat, I employ, besides the main conductor hitherto spoken of, and which is generally of low resistance, a second conductor of high resistance, shown in dotted lines." (See *Fig. 4.*) "I connect the two ends of this conductor with the two wires outside the apparatus, which are at a constant difference of potential, and I arrange the resistance of this second conductor, so that with the constant difference of potentials, the vanes do not quite begin to move. Any current passing through the main conductor will now start the vanes, and by this means the resistance

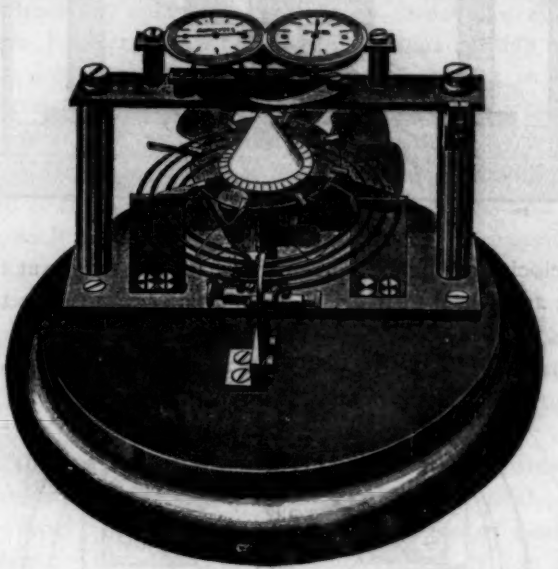


FIG. 6.

of the main conductor may be much reduced, and it will act correctly over a great range of current." The inventor sometimes obtains the constant motive force by means of the current furnished by any suitable battery.

Another form of paper-cone apparatus, differing principally in the arrangement of some of its details is, shown in *Fig. 6.**

When the apparatus is designed to measure the total quantity of electric energy, which passes over a circuit of constant current strength; that is, one in which the electro-receptive devices are in series, the thicker of the two conductors is made of such a low

* For this cut we are indebted to the Am. Inst. of Electrical Engineers, xv.

resistance that the heat from it is barely strong enough to move the vanes. Such a resistance may then be chosen for the fine wire conductor, as will permit the indications of the instrument to include the entire range of potentials to which the system of distribution may be exposed. Where this range is not very great, the heating wire of high resistance is alone employed.

As new types of instrument, the electric meters of Prof. Forbes appear to be entitled to a high rank. More extended use will, in all probability, lead to considerable modifications, without the general principle of utilizing the heating effects of the current its measurement being departed from.

The claims in the United States patent, already referred to appear to be very broad and appear to cover the utilization of air currents for the purpose of measuring the current passing. The following claims will show this to be the case, viz.:

"(1.) In an apparatus for measuring electricity, the combination, with a conductor heated by an electric current, of mechanism for indicating the current of air created by said heated conductor.

"(2.) An apparatus for measuring the strength of the air currents created by the heating effects of an electric current, consisting of vanes placed in proximity to the electric-current conductor, and so supported that they tend to rotate when placed in the fluid current, and one or more fibres, wires, or springs, which resist the rotation of the vanes.

"(3.) The combination, with a conductor heated by an electric current of vanes rotated by the fluid current created thereby, and registering apparatus connected with and operated by said vanes, substantially as set forth."

The other claims are equally broad.

When any valuable invention is brought prominently before the public, it must stand the test of priority as shown by earlier publications. Such anticipations, more or less to the point, generally come rapidly to the front, after the first publication of the new invention. The present invention does not appear to form an exception to the general rule, and already two anticipations have been brought forward. We publish the same without comment, preferring to let them be taken for what they are worth. Other similar publications will doubtless be discovered.

In the issue of the *Electrician*, of London, of October 7, 1887,

Messrs. Jehl & Rupp, of Brunn, in a letter to the editor, dated September 23, 1887, claim to have constructed and tested, as early as June, 1883, a current meter, in which the general principles of construction and operation are not unlike some of the apparatus described by Prof. Forbes. Messrs. Jehl & Rupp do not appear to have published any description of their meter, prior to Prof. Forbes' publication.

In the apparatus, as it is figured in the issue of the *Electrician* for October 7th, before alluded to, the current which is to be measured is passed through a coil of wire in the vertical glass tube *c*, *c*, *Fig. 7*, to the left of the figure. This tube communicates, by means

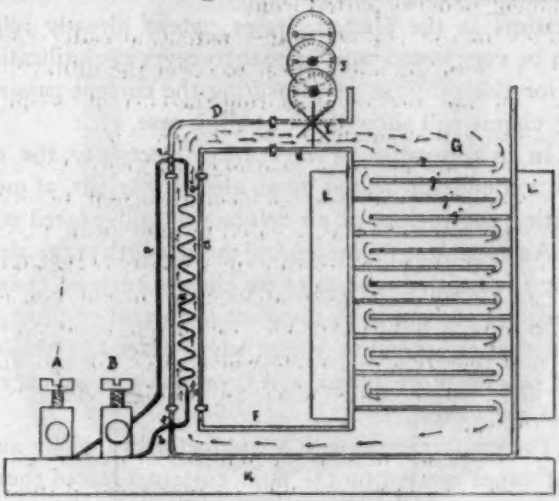


FIG. 7.

of the tubes *D*, and *E*, with a larger vessel *G*, all of which are filled with liquid, preferably olive oil. The currents set up in the liquid on its heating by the passage of the electric current, are caused to rotate a small undershot wheel, which imparts its motion to suitable registering apparatus. The dial faces of this apparatus are shown at *J*.

The larger reservoir *G*, was furnished with square sheets of copper, placed on the sides and alternating with one another. The objects of these sheets was to ensure a complete diffusion of the liquid. To ensure rapidity of loss of heat from the tank *G*, radiating plates were provided, two of which are shown in the figure at *L*, *L*.

The following description is thus given of the apparatus by the inventors in the letter to the *Electrician*, dated September 23, 1887, before referred to.

"The action of the meter was thus: When a current passes through the coil *R*, it heats the liquid at the place, thus causing a circulation, the warm liquid ascending while the cold liquid descends, as shown by the arrows. This circulation causes the undershot wheel to revolve, and its revolutions are registered by the clock work. The stronger the current the more the heat, and thus the more rapid the circulation. The warm liquid once in the tank, which is of a reasonable size, will impart its heat to all the diffusers. The surface of the glass tube, etc., is very small in comparison to the surface of the tank. It will be seen that the function of this apparatus is independent of the outward temperature, for the motion of the liquid is due only to that heat which is generated by the current. When the current does not pass, it is evident that the liquid, at whatever temperature it may be, does not circulate, as all parts are of the same temperature; but the moment the current passes a difference is produced, which causes a circulation in proportion to the current. We may mention that we tried various liquids, and give the preference to pure olive oil. It will also be seen that this meter is good for alternating currents. In conclusion, we may remark that the tests we made gave satisfaction, and we wanted to publish them, but that Mr. Jehl was called away to fit up the Edison exhibit in the Vienna Exhibition, for the Société Électrique Edison, of Paris. After the exhibition, we began our work on the disc machine, and had almost forgotten our meter."

Though we do not for a moment call into question the correctness of the statements of Messrs. Jehl & Rupp, they will, of course, appreciate the fact that the unwritten law for establishing priority of conception of a scientific principle, or the application of such a principle to any scientific apparatus, is decided almost solely by priority of publication. As to what the patent officials in different parts of the world might do for these gentlemen will, of course, depend on the character of the testimony they may bring forward, and the exact nature of the apparatus they actually constructed, as well as the record of the experiments they tried with the same.

Apart, however, from the apparatus of Messrs. Jehl & Rupp, Joseph Tavener took out a patent in England, No. 123, of 1884, for a method of, and apparatus for measuring and registering electric currents, the Provisional Specification of which is dated January 1, 1884.

In this meter, a double-bulbed glass tube (*Fig. 8*), similar in shape to the ordinary differential thermometer, has a wire spiral in each bulb, so connected that the current to be measured can be passed alternately through the wire in each bulb.

The apparatus is poised at its centre of gravity. The current being passed through the wire in one bulb, expands the air, which drives a mercury column into the other bulb. This, now, being

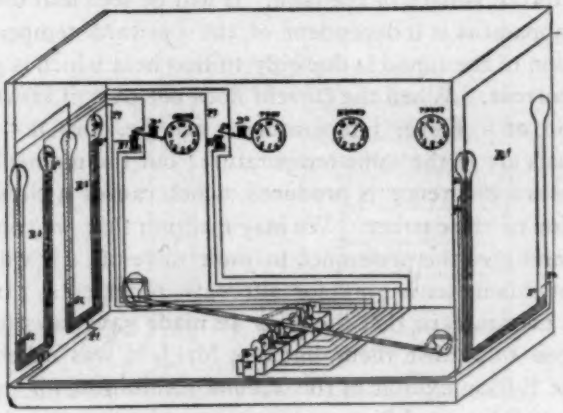


FIG. 8.

weighted, descends, making contacts which diverts the current to the other bulb. An alternate see-saw motion is thus produced, that is measured by suitable counting apparatus.

The principles involved in the operation of the Tavener meter are very clearly put forth by the inventor in his provisional specifications, as follows:

"(1.) A tube terminating in bulbs, similar in principle to a differential air thermometer, but having platinum wire or other substance, of sufficient resistance to generate heat on the passage of a current of electricity through it, inserted through each bulb; the whole being partly filled with a fluid, such as mercury, and hermetically sealed.

"(2.) This tube with bulbs, etc., rests on a support, at a point intermediate between the bulbs, and may be regarded as a hollow lever, whose support is its fulcrum, on which it turns, and whose equilibrium can be disturbed by the displacement of the contained fluid.

"(3.) The whole is so metallically connected up and arranged, that on inserting it in a circuit, the electric current will first traverse one bulb, heating the resistance, expanding the air, driving the fluid to the other bulb, making that heaviest, turning the lever, breaking connection with the one bulb, making connection with the other, heating the resistance contained in that, and in a similar manner again turning the lever—this action continuing so long as the current passes, but its frequency being dependent on the heat generated, which is equal to the product of the electro-motive force into the quantity of current passing.

"(4.) This lever with bulbs is also metallically connected with an electro-magnet in proximity to another lever, upon which the electro-magnet acts, in opposition to a spring, and acted upon by this lever in proximity to the electro-magnet is a train of wheels, whose spindles carry hands, movable over the faces of dials, on which the registrations are to be made, so that at each turn of the lever with bulbs, either connection is made and broken between it, and the electro-magnet, carrying this lever in proximity to it to move through a limited distance, affecting the train of wheels to the same extent, registering at each turn of the lever with bulbs, the same quantity of heat generated by the passage of the current, or its equivalent, the product of the electro-motive force into the quantity of current passing in circuit.

"(5.) Lastly, I particularly point out that the essential feature of my invention is the differential thermometer arrangement, or tube with bulbs, having a resistance inserted through them, and so fixed and placed in a circuit, that the registration of its movements, under the influence of the heat generated by the passage of a current of electricity shall also be a registration of the product of the current into the electro-motive force."

The following figure is taken from the patent specification of the British Patent 123, of 1884, before referred to. Some portions of the figure show apparatus connected with the meter that our space will prevent us referring to in detail.

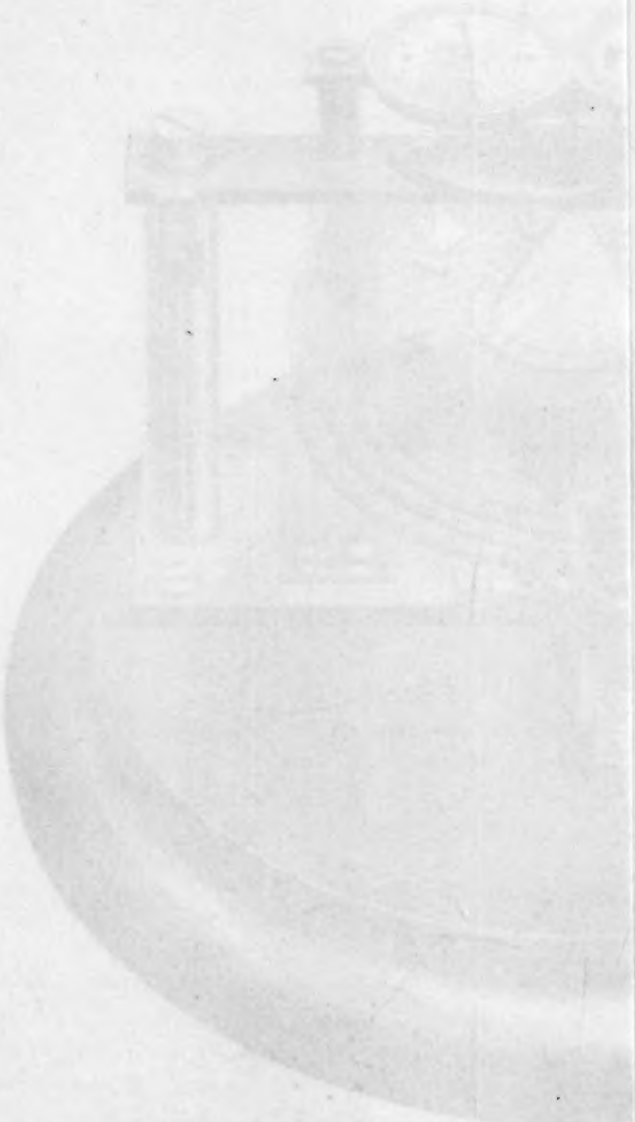
While describing the operation of electric meters depending for their action on the circulation of currents of fluid caused by differences of temperature, it will be interesting to note a form of electric meter patented in the United States, by Edward W. Weston, November 17, 1885, and numbered 330,451. In this form of meter the liquid currents are not convection currents due to differences of temperature, but are currents or movements of liquid columns traversed by electric currents, and investigated by Lippmann, Dewar, and others.

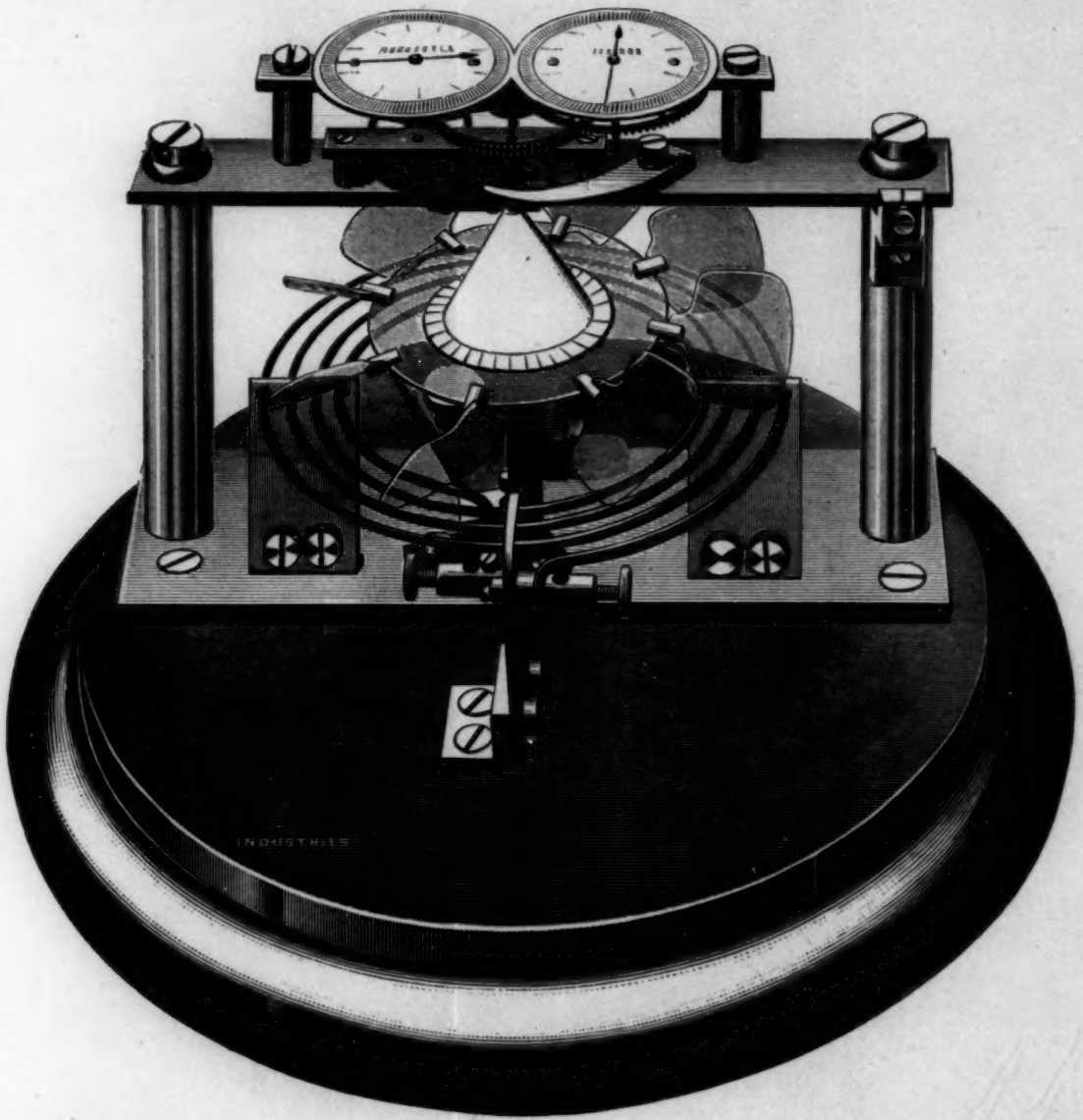
In the capillary electrometer of Dewar, which might easily be modified for use as an electric meter, a glass tube, supported horizontally, communicates with two dishes containing mercury. The tube is filled with mercury, with the exception of a drop of dilute acid. When a current is sent through the mercury in the tube by placing the terminals of any electric source in the two vessels, a movement of the drop of acid in the tube occurs, the direction of which depends on the direction of the current.

Mr. Weston has utilized some of the phenomena observed by Lippmann, in the construction of an electric meter, the general principles of which will be understood from the following description, taken from the United States letters-patent before referred to, viz.:

"The principle of the construction and operation of the instrument is as follows: If a quantity of mercury be confined in a U-shaped receptacle placed in a magnetic field, and a current of electricity passed through the mercury across the lines of magnetic force, the mercury rises in one arm or part of the U-shaped receptacle and falls in the other, the elevation of the level of the mercury being proportional to the strength of the current."

Mr. Weston's improvements consist mainly in the production of a strong magnetic field, which he claims renders the indications not only more positive, but at the same time more accurate. To obtain this magnetic field, he employs electro-magnets placed on opposite sides of the vessel of mercury. The coils of the electro-magnets are of fine wire, so proportioned that the magnetic cores are "practically saturated by any current within the normal working limits of the system with which the meter is to be used. In this way the field of magnetic force will be practically constant and uniform whenever the motor is operating, so

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that the record made is a true one of the amount of current that has passed though the instrument and the translating device."

"To utilize this as a meter, it is only necessary to cause the mercury as it rises above a given level in one tube to fall into the meter and measure the quantity thus transferred."

The apparatus is so constructed as to cause the movements of the mercury by the passage of the current, to record the volume passed by a tilting motion, caused by the over-balancing of a tray when a certain quantity of mercury has accumulated thereon. These oscillations are recorded by suitable wheel work.

We believe that this instrument has never been put into actual use.

CENTRAL HIGH SCHOOL.
Philadelphia, November 2, 1887.

AN ELECTRICAL CURRENT METER.

BY PROF. GEORGE FORBES, F.R.S., Etc.

[*Read at the Stated Meeting of the* INSTITUTE, *held Wednesday, Oct. 19, 1887.*]

JOSEPH M. WILSON, President, in the Chair.

THE PRESIDENT.—I beg to introduce to the INSTITUTE, Prof. Geo. Forbes, of England, who will exhibit and explain the Coulomb-meter, a new instrument for electrical measurements.

PROF. GEO. FORBES.—*Mr. Chairman and Gentlemen:* During the whole time that I have been interested in the practical applications of electricity, the subject which has most fully occupied my mind has been the distribution of electricity from central stations. In the period when there was a great excitement about electrical matters in England, some five or six years ago, there were numerous propositions for lighting from central stations, districts and towns. None of these propositions, or very few indeed, were feasible. It has long been known to electricians, as a matter of fact, that it was an impossibility in the earlier stages of electric lighting to supply a great district, or, to too great a distance from the central station. Still, a great deal was possible, and it can be done either by the

old methods by the continuous current up to one-quarter of a mile in an economical way; beyond that, there was no system available. Fortunately we are now possessed of a system which has become thoroughly practical, and which solves the difficulty of lighting at great distances, and that is by alternating currents generated at central stations and of high tension; these currents being transmitted over a thin wire to any distance required. Up to ten miles, the system has been tested already, and the currents are passed through the apparatus, known as secondary generators, transformers and converters, and are reproduced in currents of ordinary tension for the lighting of rooms, such as we have here. This room is being lighted upon that very system.

Now, even when it was thought that possibly we might introduce a direct current to supply power, and supply electricity which flowed through the conductors in the same direction, there was a great difficulty in the way of the introduction of electricity, and that was the lack of a satisfactory meter. But when electricians realized the fact that in future, that is to say, at any rate, until we have a secondary battery, which is cheaper and lighter than anything we have at present—when electricians realized that we shall be using this alternate system of distribution, the fact was forced upon them, that there was absolutely nothing which had been suggested, which could measure the consumption of electricity in one house.

A great many kinds of meters have been devised at different times; all of them, I believe, were intended to be used with continuous currents as distinguished from alternating currents. These may be divided into two classes: the electro-chemical and the electro-magnetic.

The electro-chemical meter depends for its action upon the chemical action which takes place in a liquid when a continuous current is sent through that liquid, and, therefore, is utterly inapplicable to an alternating current, because when we are using electric currents, the direction of the current is being reversed in the circuit hundreds of times every second.

It has been found that all suggested electro-magnetic meters are also unsuitable for alternating currents. The principal objection which has been found with them has been this: that the indications of the meter are not always proportional to the current

that is passing through. It depends partly upon the speed at which the machine is being driven, the rapidity of the alternations, and direction of the currents. Thus, at two rates of speed of the engine, the same current may be flowing into a house and the electro-magnetic meter will indicate totally different supplies of current to the house. Of course, that is not suitable. It is essential that we should have some meter, which is capable of acting the part of the gas meter, only in a more reliable manner.

It is equally important for the consumers and suppliers that such a meter should be provided. It is utterly unsuited to practical people to deal with a general supply of electricity when the charges are made at so much a light per annum; where the supplier does not know whether the consumer is using his light day and night, or only a few hours each night, and when the consumer feels pretty confident that he has a right to light all his lamps the whole twenty-four hours. It is utterly impossible that such a system can last as a basis. The necessity for a meter has forced itself upon everybody.

The chief requisites of a good meter seem to me to be these: It should be accurate within a few per cent. over a very considerable range of current. It should be readable by the consumer as well as by the producer. It should be perfectly simple and as cheap as the gas meter.

It has been found very difficult even in those meters that have been constructed with fair success for the continuous current to comply with the first requisite, that they should be accurate over a considerable range, say from one to twenty lamps, which has generally been beyond the capabilities of accuracy. And in many of the meters which have been constructed to attempt to supply the want of a basis, it has been impossible for the consumer to see at what rate he was using up the electricity.

It was about nine or ten months ago that it was actually forced upon me in a very marked manner, by people who were going to supply the alternating current on an enormous scale, that there really was no meter; that people had been working for it years and years, but had not found it; and it was forced upon me that every effort must be made by persons who were interested in the progress of electric lighting to try to produce such a meter. It seemed to me that any system founded upon the chemical action

of electricity could not succeed with alternating currents. It also seemed that any electro-magnetic machine is certain to give different readings for the same current when the generator of electricity is going fast or going slow.

The next most important electrical action that we are acquainted with is the production of heat, in which the total quantity of electricity used up is wholly converted into this new form of energy; and it seemed to me that if we could devise some simple means of measuring the quantity of heat generated in the conductor by the electric current in the course of so many minutes, we should have the solution of the problem.

And here, also, was a difficulty. The amount of heat created is proportional to the square of the current; thus, if in one experiment I use one ampère of current and in another two ampères of current, the apparatus being the same in each, I am generating four times the heat in one case as in the other. Therefore, the heat evolved is not entirely proportional to the current passed through.

Still, it seemed to me possible to devise an apparatus founded upon the generation of heat which would be accurate. My first experiment was attempted in a very simple way. I cut out a circle of paper, and cut it into a spiral with a pair of scissors, and supported it by a needle from the top of a stick, so that it hung like a spiral worm around the stick. I put an electric wire carrying a current underneath this spiral, and I found that the amount of heat necessary to turn the spiral was exceedingly minute. I tried other sources of heat first, and I found that when the spiral was put under a glass shade, by making a hole in the base of the instrument and putting half an inch of my thumb through the hole, the heat generated was sufficient to make that spiral turn around. You can judge what a very delicate instrument I had.

I was then in communication with a gentlemen, whose name I always like to mention; this is a gentleman connected with Wheatstone in the development of all his extended telegraphic apparatus used by the British Post Office Department: I refer to Mr. Strohm, one of the most perfect mechanicians we have in England. I was in constant communication with him at this time, and he assisted me enormously in the mechanical details of the work. He assisted me not only by his mechanical knowledge, but

by keeping my spirits up when I got despondent, so much so that I felt that he had a great deal to do with the invention; and if it were not that I should commit a German pun, I might call the instrument a Strohmmeter, which would indicate his assistance at the same time. [Laughter].

The instrument which you have before you now is an extremely simple one. A gentleman who saw it in New York, said: "I do not know anything about electricity, but I could have invented that thing very easily. It is ridiculously simple, and it looks as if that is the only form which it would have taken."

I may say it took 10,000 observations and the manufacture of the apparatus in hundreds of different forms before I arrived at what I considered a really practical form of mechanical instrument.

I have a lantern slide which will, perhaps, make it more clear than by drawing attention directly to the instrument, and we can examine the instrument more carefully after the meeting is over. This was taken from a photograph, which gives an extremely accurate idea of the instrument. This (pointing to the instrument on the table) is not the instrument from which the photograph was taken. We have had a great many made, and have had the mechanical arrangements altered to find which was the cheapest to manufacture. Economy is of importance.

The instrument consists essentially of this flat spiral which you see going around in a horizontal plane, consisting of four turns of iron wire. About it there are eight vanes, inclined at an angle of 45° to the horizon, which are attached to small pieces of pith by slots in the pith; and in the same manner, these eight pieces of pith are attached to the circular disc of mica which lies horizontal, which has a hole in its centre, filled up by the base of the thin paper cone. At the top of the cone, there is a jewelled cup, a ruby cup, which is supported on the point of a pin attached to the base of the instrument. The jewelled cup lies in the centre of the pinion which forms the first member of the train of wheel work. The wheel work multiplies ten-fold a good many times over, and finally we are brought to two of the wheels on the arbors of which indexes are attached, pointing to two dials; one dial reads from units to hundreds, and the other reads from 100 to 10,000.

The unit which is adopted is the English Board of Trade unit, which was fixed by the Board for commercial use. It is the

quantity of electricity which passes through a 100-volt lamp using one ampère of current in ten hours. Therefore, if I see an indication of ten units in a night, I would know that 100 ampère hours had been used in the night. If the lamps are not 100-volt lamps, but fifty volts, we would have to multiply by fifty and divide by 100.

You have been wondering what this tongue of metal is which rests just above the first pinion, the jewelled pinion. That is to enable you, by means of a screw at the base, to lift up the whole horizontal mica disc and the cone above it, and the vanes attached to it, and lift it up until it is pressed against the tongue of metal of which I have spoken. That enables you to carry the apparatus about without danger of the parts being injured.

I think these are all the details which I need to show you; in fact, I have explained every part of the instrument. In the instrument before us, the dials differ slightly from the one shown on the screen. The multiplication has been increased 1,000-fold. A worm comes into play attached to the arbor of the most slowly-moving wheel of the train. That worm works in two wheels fixed upon the same axis. One of the wheels has ninety-nine teeth, and the other has 100 teeth, so that in every revolution of these two wheels together, one wheel has gone one hundredth of a revolution more than the other, and the index on one wheel points to a dial fixed on the other wheel; and thus the number of hundreds of revolutions is counted on one wheel, while another index pointing to the first wheel indicates the fractions of a revolution of one of the wheels. One of the dials measures up to 100 revolutions, and the other measures down to one-hundredth of a revolution.

I ought to say, that when I left England I left four instrument-makers in London with instructions to build copies of this instrument slightly modified; my object being to see at what cost each of the different makers would produce them, and the accuracy obtained by different makers. In these new meters I am abolishing the method of counting which I last described, and I am also abolishing the two dials with 100 divisions. I am now introducing four dials like the ordinary gas meters; they will be more commercially satisfactory.

I would like to give you some idea of the range and accuracy of this instrument. In the first place, let me tell you that all instruments which I have had made with smaller conductor and smaller vanes have given me identical results; that is to say, I am perfectly confident that I shall be able to produce meters which will give exactly the same readings. That is a considerable step when we commence to manufacture instruments on a large commercial scale.

I will give you now some instructions as to how these instruments read. I have constructed them generally with the object of using them on a lamp which consumes three-fourths of an ampère. Of course, by modifying the resistance of the conductor, it is perfectly easy to suit them to a lamp which consumes any current we please. I always plot my results down upon a curve, and thus we are enabled to compare one result with another by a glance of the eye.

I measure on a horizontal line the current strengths beginning at 0, and going up to 10 and 20. A meter which was intended to commence indicating at three-fourths ampères, I have used up to twenty amperes with perfect success. That is, we have a fifty-fold range; and I have used my meter either from one lamp to thirty lamps, or ten lamps to 300 lamps.

Measuring the strength of the current on a horizontal line, I measure in a vertical direction the ratio of the current to the speed of the meter. You will easily see that the ratio ought to be perfectly constant if the meter is a good one.

Taking the curve indicated at any point here (on the vertical line) we have a certain rate of speed, one, three, five, six, going say to five. This is a current of two ampères (horizontal). I find as a matter of fact that the instrument begins to start with about half an ampère, but the speed is very small indeed, and therefore the point corresponding to one-half ampère is very high up, and on nearly the same level as the other reading. With three-fourths of an ampère I get a reading of about six or seven. With one ampère I would get my reading about five, and with two ampères it is about five, and with ten ampères it is about five. The curve takes this kind of form: it sinks very rapidly until it comes to about one ampère, and from that point onwards it is quite horizontal until the wire is made red hot. If it is horizontal, it means that the

quantity of electricity which passes through a 100-volt lamp using one ampère of current in ten hours. Therefore, if I see an indication of ten units in a night, I would know that 100 ampère hours had been used in the night. If the lamps are not 100-volt lamps, but fifty volts, we would have to multiply by fifty and divide by 100.

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ratio of the current to the speed is perfectly constant at whatever rate we may be passing the current through the instrument, and that is the condition of a perfect meter. The variations are extremely small.

Yesterday I had a telegram from my assistant in England, in regard to the first of the new batch of meters which is to be the type of all future meters. It states that from the moment the current reached this position (indicating on the diagram), which is one and one-half ampères, it never varied two per cent. from a straight line the whole way up to twenty ampères. I do not mention this, because it is something I have not had before, for my meters have given this result over and over again, but, mark this: I gave instructions to the instrument-maker before I left England; he was left to make the instrument from the design I gave him, and I mention this to show that a good workman is able to produce commercially a meter which involved months of work for me in the production of the first one.

I have shown this meter to assemblies of electricians, one was at the British Association, at Manchester, just before I left England, and the other was at the American Institute of Electrical Engineers, at New York, last week. At both places, a great many questions were asked me, and it will save time now if I answer one: "What influence has the temperature of the room on the meter?"

At first sight you would think this a very serious matter. To begin with, I will answer that, as a matter of fact, I find that it has no effect whatever. It is not difficult to see the reason for this. We are measuring the strength of the convection of currents of air. The strength of the currents depends upon the difference in temperature between the air in the neighborhood of the heated wire, and the air in the neighborhood of the glass. It does not matter whether the air to start with is at zero or 90°, that difference remains the same, and that is what causes the convection of the current of air. The difference remains the same when the wire is heated above the atmosphere to a certain extent. The only influence which the temperature of the room would have would be owing to its heating the wire; this might produce some influence, but not enough to influence the working of the meter to any extent.

Another question I am frequently asked is, whether it would not be better to make a hole in the top and have a free circulation of air through the glass shade. My answer is that it would be somewhat advantageous, but there are objections to the admission of air to a piece of delicate wheel work, and as I have worked until I got the instrument to act thoroughly well in an enclosed space, I think it would be better to let it remain as it is.

I may mention that in this instrument the base to which the wheel work is attached is made of slate. In some I have had it attached to a plate of brass, which got very hot, and absorbed a good deal of heat, and took a long time to cool down at the end of the experiment. By reducing the metallic parts to as small a mass as possible, I cause the instrument to stop very soon after the current has been taken off. In fact, I believe that at present any accumulation of measurement after we have stopped the current is about balanced by the want of measurement when we first put on the current while the wire is getting heated, and the circulation of the air is getting up its swing.

Other questions will no doubt occur to gentlemen here, and I think it best to leave those questions to be asked, and I can answer them when I hear what suggestions are thrown out. I think I shall find now, as I have noted on two previous occasions, that a great many gentlemen here who are very ingenious, and who see the working of the instrument very thoroughly, will make very sound practical suggestions, but in the course of the enormous number of alterations I have made in this instrument, I think I have eliminated all the bad features possible, and reduced it to the most practicable form.

I will now put on a current which I estimated to be some ten ampères. You see the instrument is already going around—(after about ten seconds),—the vanes are now revolving, and if we cared, we could take the speed at which they revolve, but as I have no measuring instrument connected with it, it would be of little interest.

I will now increase the speed by putting on two cells of battery and you will almost immediately see it gradually increasing in speed. It takes a little time for the speed to get up to its full rate. With a very small current of one or two ampères, it takes about two minutes to get up to its full speed, but with the higher cur-

rents it goes very rapidly to its reading. It is now going at a considerably greater speed than when I looked at it last. It is going quicker than it was with a single cell in the ratio of 6 to 10.

We have now in this room illumination by the alternating current system. I forgot to mention that these instruments having been made both for alternating and continuous currents, it was with some interest that I compared the readings of the two currents. I rather expected to find that the self-induction in the wire might cause the wire to have a different apparent resistance with the alternating current from what it had with the continuous current. I have tested this very carefully and find that there is no difference in its standard. With ten ampères direct, it goes with the same speed as with ten ampères continuous.

I will now connect the instrument with the alternating current system, and we will then see what effect we have. You notice that it has stopped. What current have we got?

PROF. HOUSTON.—Three lights.—(Instrument starts slowly.)

PROF. FORBES.—Prof. Houston has kindly arranged the wires, so that I am able to switch on these lamps in the centre of the room, or this one here, which is the equivalent of nine of the other lamps.

We will make a measurement. I am afraid I have not mounted the instrument very delicately on this table, and it does not seem to be going at all with its usual vigor, considering that three ampères are going through it. It has only been on for about a minute, and it requires a few minutes to come up to its full swing. I am afraid there is a sticking point in it. In coming over from New York, I broke one of the vanes off, and I had quite a little trouble in fixing it. There seems to be one point where it sticks and has difficulty in getting over. I am afraid it is that vane. It is possible that the vane I put on this afternoon jams somewhere, as it always sticks in the same position. We will put on the nine ampère lamp and see how it goes. We now have the nine ampère lamp at work on it. I have no doubt, you will soon find it going on all right; even if there is a little dust touching any one of the vanes, we have enough current to drive it. I am certain I shall find a bit of dust, if there is a halting point. Nevertheless, it goes merrily around.

I will take the speed of revolution, when it comes up, to its full swing, and measure the time occupied by ten revolutions of the wheel—thirty-eight seconds.

DISCUSSION.

THE PRESIDENT.—The subject is now open for discussion.

MR. COOPER.—I now repeat the question, whether the instrument works the same under varying conditions of humidity?

PROF. FORBES.—I have never made any special measurements, either for humidity or temperature, but I have observed the same instrument continuously day after day in the laboratory where there was no fire, and where it was subject to all the changes in humidity, and have never noticed any difference in its working.

MR. COOPER.—It seems to me that the surrounding atmosphere, when very absorbent, would be apt to dissipate the heat through the whole volume of air; you have the same current throughout, and the convection currents are not relatively so hot.

PROF. HOUSTON.—Speaking from a practical standpoint, I think Prof. Forbes is to be greatly congratulated for the success he has made in the development of his coulombmeter. Now that successful distribution of electric lighting by means of the alternating current is an assured success, and the areas lighted can be extended almost indefinitely, he has succeeded in removing almost the only difficulty or obstacle in the way of the commercial sale of the electric current. It is true that before Prof. Forbes' coulombmeter was invented there had been meters for direct and alternating currents, but I do not think that any electrician would claim that the meters for alternating currents before the invention of Prof. Forbes's coulombmeter could be considered a very pronounced success.

There are three properties that may be utilized in the measurement of the electric current, viz.: the chemical, the heating and magnetic power. I think Prof. Forbes is perhaps the first who has thought of using the heating power of the current for the measurement of the number of coulombs that pass. He certainly has made a meter that possesses this remarkable property, that it will serve alike for direct or alternating currents, and I believe with the same standard. That latter is a very remarkable achievement in itself.

This coulombmeter, it seems to me, from a practical standpoint, has in it the germ, if not the completion, of a good instrument, because it fulfils those conditions which Prof. Forbes has so clearly laid down, viz; that it shall be accurate, not for a single measurement only, but through a range of form one to thirty or any number of lights; that it shall be understandable by the consumer. If the consumer wishes, he can tell about the amount of energy he is using. It is simplicity itself; a simple mechanism for being moved by convection currents, and a registering apparatus to register the rapidity of the movement.

I can congratulate Prof. Forbes also from another standpoint. I have this evening read his U. S. patents. I have had some experience in patents, and I think he has a base patent; although we do not know what the journals may have in store for us. I think he is the first to use heat in this manner.

I would like to make some correction of the Professor's remarks. He gave too much credit to the good workman who could build the instrument from his instructions. He laid too little stress upon the clear instructions given to the workman. [Applause.] I think this is rather an important point. We once had a discussion on this floor as to the comparative value of pure science and practical science. I remember that pure science was lauded and practical science was looked upon as beneath the dignity of a scientific man. It seems to me that the truest science is what will back its convictions by its money. The truest science is that which can put down on paper just what the scientist claims ought to be, and which will work out, practically, so clearly that by the time, as in this case, the scientific man has crossed 3,000 miles of ocean, he can be advised that an instrument has been constructed, according to his description, which will do practical work. [Applause.]

On motion of Mr. Houston, the thanks of the INSTITUTE were tendered to Prof. Forbes for his valuable paper.

FLASH-LIGHT PHOTOGRAPHY.

By Mr. John Carbutt.

[*Being the Substance of Remarks made at the Stated Meeting of the* Institute, *held Wednesday, October 19, 1887.*]

Jos. M. Wilson, President, in the Chair.

Mr. John Carbutt.—*Mr. President, Ladies and Gentlemen:* I take pleasure in bringing to your attention this evening the latest thing in instantaneous photography at night; although it is not instantaneous, for the duration of the flash is perceptible. It was but recently brought to the notice of the public at the meeting of the Photographic Society, in New York, on Tuesday last. Being a member of that society, I was so far interested in the subject as to go over to see its performance, and was very much struck by it.

While at first I thought the method would be useful only for social entertainment, I can now see where it might be of use in scientific investigations in photographing the interior of mines, geological strata, breasts of coal or in any place where it might be of advantage to have a photographic representation of objects, which could not be reached by daylight.

The invention is the outcome of investigations made by Dr. H. G. Giffard, of New York, who, on reading a description of a patented method of quickly igniting magnesium powder, the invention of a German and patented in England, saw that the material used was of what he considered a dangerous nature, and that it would deter those unacquainted with chemistry from using it. He thought first of using gunpowder to ignite the magnesium powder, but finally decided upon gun-cotton, using the kind which is least explosive in its nature, the variety called collodion, which is not so rapidly explosive as that used for projectiles. The results of his investigations were so satisfactory that, having a little party at my house last week on the occasion of my daughter's birthday, I thought that before they broke up, I would endeavor to secure a picture of them by the new method, it would be a most interesting memento of the occasion, and might be followed by others for a more useful purpose.

Before showing you this light, I will show you some instantaneous pictures, which I took at the University last week of the young athletes in the act of vaulting, and while the pictures are upon the screen I will endeavor to demonstrate the rapidity with which the exposures were made. The first shows the first step made by the champion high jumper, Mr. Page, as he makes his spring before taking the jump.

The second is the five-feet jump. You see him just over the bar. Those who saw this performance will recognize that he turns around and faces the goal from which he starts.

The third is the five-feet-six jump, in which you see that his body is on the turn.

The fourth is a representation of the extraordinary feat of Page breaking his own record by jumping six feet four inches.

The fifth represents Tom Ray vaulting with a pole and clearing the bar at eleven feet four inches. The sixth is the eleven-feet-six jump. In this jump, you will notice that after he rises to about the height of the pole, he climbs up it, hand-over-hand, about three hands, and elevates his feet over the pole and holds on with his left hand until he gets his feet clear, and then throws himself forward and the pole backward, using the momentum to pitch his body over the bar.

This last picture is the group of children, the little party at our house, which we called our "Donkey Party;" it was taken by the flash which will be presently illustrated to you.

It will be readily seen how portable the photographic apparatus is. The apparatus now provided is of such a portable nature that wherever anybody can go with his body he can take it along. I have in my hand six charges. If the President will kindly sit for a moment, I will photograph him.

I have here an extemporized arrangement upon which to burn the magnesium. Here in this paper are twenty grains of pyroxyline, commonly called gun-cotton, and here is a piece of asbestos underneath. I scatter fifteen grains of magnesium powder on the gun-cotton, and by touching the gun-cotton with a lighted taper it will explode with a puff and ignite the magnesium-powder. All now being in readiness, I will put out the lights.

A VOICE—Is your plate in?

MR. CARBUTT—I think you are right, Mr. Chambers. You have been where photographers have been at work before.—(Puts in the plate, fires the preparation, which ignites with a brilliant and diffused flash.)—The exposure is made, and the picture is taken. I will endeavor to show you the results at the next meeting; there are no facilities here for developing.

On motion of Dr. Wahl, the thanks of the INSTITUTE were tendered to Mr. Carbutt for his very interesting illustration.

THE REACTION OF A LIQUID JET;

Being a Review of § 522 and § 523 of Weisbach's „Ingenieur- und Maschinen-Mechanik, Erster Theil; Fünfte verbesserte und vervollständigte Ausgabe, Braunschweig, 1875;"

With some additional matter.

BY PROF. J. BURKITT WEBB, Stevens Institute, Hoboken, N. J.

(*Continued from page 156.*)

The effect of placing $F = G$ is best seen by means of eq. (24), which becomes

$$h' = \frac{c^2}{2g} = \frac{h}{1-1} = \infty \qquad (24')$$

and shows that the velocity will be infinite if the water is to be furnished at A fast enough to keep the vessel or pipe full at F while gravity is free to act upon it in its passage from A to F. Eq. (49), which should read

$$V = 2\,F h' \gamma\,(\sin\alpha - 1), \qquad (50)$$

gives, therefore, an infinite value for V, as it should. Another form of (24′) is,

$$h' = \frac{c^2}{2g} = \frac{h=0}{1-1} = \text{any value}, \qquad (24'')$$

according to which if A be on the same horizontal line with F (see *Fig. 3*) the pipe between may be of uniform section and remain full; or, taking friction into account, A may be at such a height above F that a column of water of the height $h = A\,F$, will just balance the friction between A and F. The difficulty in supposing $h > 0$ and $F = G$ when there is no friction is that the

descending stream will fall clear of the pipe (as shown in *Fig. 4*) when the distance $A\,F$ is large; if it is small the water may adhere to the pipe enough to keep it full, as is supposed to be the case in *Fig. 2*, above A. The formula, however, does not take into account either friction or adhesion.

From (5) and (7) we obtain for any values of F and G,

$$h = \frac{G^2 - F^2}{F^2} \cdot \frac{c_1^2}{2g} \qquad (5')$$

from which it appears that for h to have a minus value $F > G$, a case shown in *Fig. 5*. The general statement may also be made

Fig. 3.

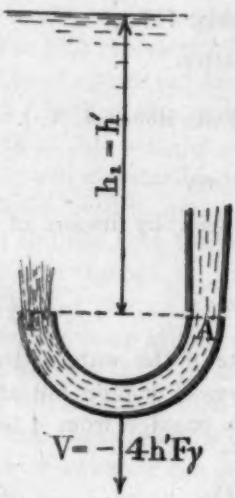


Fig. 4.

Fig. 5.

that if F be too small for G and h, as determined by eq. (5'), the velocity c_1 will be checked, *i. e.*, the water will not be able to flow away from A as fast as supplied, while if F be made too large the water will cease to fill the pipe.

The last value for V given in (49) is superfluous, and the statement that "V does not act upward, but downward," should be taken as meaning that while in (43) and (44) V will act *either* upward or downward, according as $\sin \alpha$ is greater or less than $F \div G$, in eq. (50) it will always act downward, because $\sin \alpha$ cannot be greater than 1.

Equations (51) and (53) should be written

$$H = 0 \text{ and } V = -2Fh'\gamma\left(1 + \frac{F}{G}\right) \qquad (52)$$

omitting "$= R$" because R is the reaction of the out-flowing jet and not the combined reaction of both, and

$$V = -4Fh'\gamma \qquad (54)$$

This latter value of V is shown in *Fig. 3*. Eq. (55) should also be written without R, thus;

$$H = 0 \text{ and } V = 2Fh'\gamma\left(1 - \frac{F}{G}\right) \qquad (56)$$

and (57), obtained by putting $a = 90°$ in (46) and not on the supposition that $F + G = 0$ in (55) (56), should read

$$V' = 2Fh'\gamma \qquad (58)$$

It is thus evident that the statement as to the diminution of weight refers to (55) (56) and not to (57) (58), because, in view of eqs. (43) (44) and the distinction pointed out between V' and V, it must be clear that the weight is affected by V rather than by V' alone. Were the surface at A an actual free surface, no water being supplied, so that h, c_1 and c were decreasing, the weight would still be reduced by V. This becomes evident when we consider that the downward pressure on the vessel in *Fig. 924* really arises from the impact of the stream upon the converging sides, as we shall show more clearly later; therefore, if we suppose the supply to be suddenly discontinued the stream through the vessel will not be immediately changed and we shall have no sudden change in the weight, but a gradual one as h, c_1 and c change.

The truth of the above is also seen by considering the section G to be made a differential distance below the free surface, which gives a velocity through G equal to the velocity downward of the free surface.

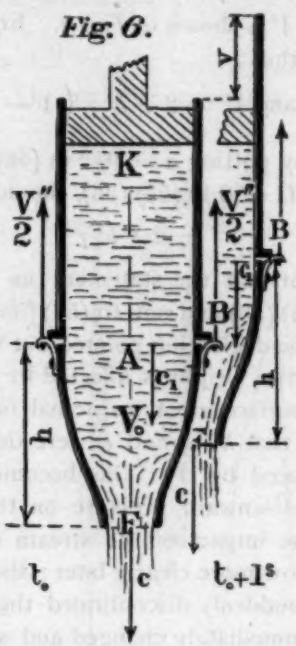
In the American edition (49) is followed by equations for the values of R on the supposition that it is the resultant of H and V, but if R is to be the reaction of the out-flowing jet these should be striken out. Eq. (53) lacks the minus sign; (51) is lacking and (53) seems to have been obtained from the equations for the values of R, above alluded to, the sign being lost on account of a

radical sign. The same ambiguity also exists in regard to h, which should in the latter part of the analysis be changed to h'.

In *Fig. 924*, "E" should be A.

We will now apply the preceding principles directly to the solution of a simple problem, which, apart from its intrinsic interest, will serve still further to elucidate the method itself.

Fig. 6.



Let the vessel $A\,F$, *Fig. 6*, be moved vertically upward with the velocity

$$v = c_1 \tag{60}$$

so that we have by eq. (31)

$$c_2 = v - c_1 = 0; \tag{62}$$

the supply of water must therefore be at rest with respect to the earth. This will be attained if the air-tight piston K be fixed to the earth and the supply-pipe B moved upward with a velocity v. A small opening, or crack, of constant width, between B and $A\,F$, will secure the independent action of $A\,F$ and insure atmospheric pressure at A; inasmuch, however, as B may be supposed frictionless in sliding past K it might, practically, rest against the vessel

and the whole be thus moved up more conveniently together. Of course, $A\,K$ must be less than thirty-four feet to keep the water up to K.

Equation (5) gives also

$$h = \frac{c^2 - c_1^2}{2g} = \frac{c^2 - v^2}{2g}, \tag{64}$$

and (7) becomes

$$Q = F\,c = G\,v. \tag{66}$$

Consider now the vessel of water as a separate, or self-contained, system, included between the sections G and F. This system contains the constant amount L_0 of kinetic energy in the flowing water; it is acted upon by the vertical force V'', tending to lift the vessel, and each particle of water is pulled downward by gravity; neglecting the uniform atmospheric pressure on the outside of the vessel and throughout F and G there are no other external forces acting upon it; the system also gives out each second the same amount of water as it takes in but the water is received at rest with reference to the earth and discharged at a velocity $c - v$, thus carrying away from the system the energy per second, see eq (37),

$$L_2 = \frac{c^2 - 2\,c\,v + v^2}{2g}\,Q\,\gamma \tag{68}$$

The energy of the system being constant, the work done on it by the external forces must equal the energy discharged, which gives us the equation:

Work done by V'' plus work done by gravity $= L_2$.

The work done by V'' per second, is

$$L_3 = V''\,v. \tag{70}$$

To find the work done by gravity, we must ascertain the height through which each particle descends while under its influence in its passage through the vessel, this height multiplied by the weight of water discharged per second will give the work required. The time taken by a particle to pass through the vessel is the same as that required to empty or fill it; therefore,

$$\text{time from } A \text{ to } F = \frac{V_0}{Q} \tag{72}$$

where V_0 is put for the volume of the vessel. During this time the vessel rises a distance $= v \frac{V_0}{Q}$ and the particle descends therefore through the height

$$= h - v \frac{V_0}{Q} \tag{74}$$

with respect to the earth, so that we have for the work done by gravity per second

$$L_4 = Q\gamma \left(h - v \frac{V_0}{Q}\right),$$

which by (64) reduces to

$$L_4 = \frac{c^2 - v^2}{2g} Q\gamma - v V_0 \gamma. \tag{76}$$

Combining these results we have, according to the principle above explained,

$$L_3 + L_4 = L_2$$

or

$$V'' v + \frac{c^2 - v^2}{2g} Q\gamma - v V_0 \gamma = \frac{c^2 - 2cv + v^2}{2g} Q\gamma,$$

which reduces to

$$V'' = V_0 \gamma - \frac{Q\gamma}{g}(c - v). \tag{78}$$

The first term of this value is the weight of the water in the vessel, the weight of the vessel having been neglected, otherwise $-v \times$ weight would have appeared in eq. (76), and consequently the value of V'' would have been increased by the same amount; *i. e.*, it is the weight of the water between the two surfaces at A and F throughout which the pressure is atmospheric. The second term is the momentum of the issuing minus that of the entering water, both taken with respect to the vessel; or, it is the increase of momentum, equivalent also in this case to the momentum of the jet with respect to the earth.

It is to be observed that the supposition made in producing eq. (78) introduces the weight of the water in the vessel, which is not involved in the supposition made in producing the value of L in Weisbach's treatment. *Fig. 6* shows the apparatus in two positions; first at any time t_0 and then at the time $t_0 + 1^s$, or one second later.

Attention may here be called again to the difference between V', the vertical component of the reaction, R, of the out-flowing jet; V, the algebraic sum of V' and the reaction of the in-flowing jet; and V'', the weight of the vessel of water $- V$.

The following problem involves the above principles with the exception of the weight of the water.

Suppose a common syringe to be placed in a horizontal position and full of water, which is to be forced out through the nozzle in a horizontal stream; what difference will it make, if any, in the force required whether (*a*) the barrel of the syringe be held in a fixed place and the piston pushed in, or (*b*) the handle of the piston be rested against a fixed support and the push applied to the barrel, the velocity with which the water passes through the nozzle to be the same in both cases?

We will now show that a calculation of the pressure against a gradual contraction in a water pipe results in the same value for V as given in (43) or (44), which may be written:

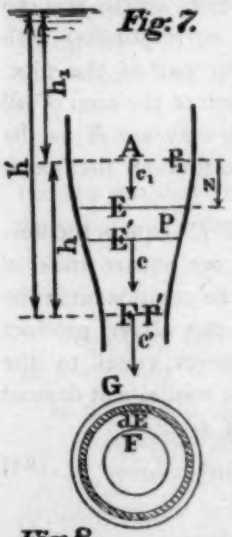


Fig. 7.

Fig. 8.

$$V = Q\frac{\gamma}{g}\, c \sin \alpha - Q\frac{\gamma}{g}\, c_1 \qquad (44')$$

= outflowing minus inflowing momenta, and becomes for $\alpha = 90°$

$$V = Q\frac{\gamma}{g}\, c - Q\frac{\gamma}{g}\, c_1; \qquad (80)$$

and also in the same value of V'', as defined in the last problem,

$$V'' = V_0 \gamma - Q\frac{\gamma}{g}\, c + Q\frac{\gamma}{g}\, c_1 \qquad (82)$$

of which (78) is a special case. V'', not shown in *Fig.* 7, is the longitudinal tension in the pipe above the contraction.

Let a vertical water-pipe change by a gradual contraction from a section G at A to a section F at F. The pressure of the water on the non-cylindrical part will have a component P in the direction of the axis of the pipe, which we will calculate using the method of "plane sections." This method takes for an element of

volume the differential volume between two consecutive planes perpendicular to the axis of the pipe and supposes that the velocity and pressure are constant throughout any one such element. These sections may be supposed to be fixed to the pipe or to move along with the water, in which latter case the planes may be supposed to separate from each other, as they move on, just enough to allow for the contraction of the section, and thus keep the differential volume constant. The method is correct only when the contraction is infinitely long, though sufficiently so, as far as practical results might be affected, for all long contractions, it does not therefore lead to a conclusive proof though it furnishes an example of cases where an inaccuracy in the method of proof leads to no error in the particular results obtained.

We shall suppose the planes fixed, they will therefore cut the tapering surface of the pipe into a series of more or less tapering rings, one of which, $E\,E'$, seen in elevation in *Fig.* 7 and in horizontal projection in *Fig.* 8, where it is cross sectioned and marked $d\,E$. The horizontal projection of the tapering part will be two concentric circles F and G, the space between which will be entirely made up of all the shaded rings $d\,E$ corresponding with all the rings $E\,E'$, which make up the tapering part of the pipe. The pressure P, which is to be found, is therefore the sum of all the pressures upon the rings $d\,E$, so that we may use E as the independent variable and avoid any consideration of the exact shape of the converging part of the pipe.

Evidently the total pressure on the ring $E\,E'$ equals the surface of the ring multiplied by p, the pressure per square inch of the water against that part of the vessel, and the component in the direction $A\,F$ of the total pressure equals the above product multiplied by $\sin\,\alpha$; the area of $d\,E$ is, however, equal to the sloping surface of the ring into $\sin\,\alpha$, so that the component desired may be expressed as the product of p into $d\,E$, *i. e.*,

$$d\,P = p\,d\,E. \tag{84}$$

By § 427 (Am. ed., § 400,) we have

$$p = p_1 + z\gamma + \frac{c_1^2 - c^2}{2g}\gamma \tag{86}$$

also

$$p' = p_1 + h\gamma + \frac{c_1^2 - c'^2}{2g}\gamma \tag{88}$$

from which we get

$$p_1 + \frac{c_1^2}{2g}\gamma = p' + \frac{c'^2}{2g}\gamma - h\gamma, \tag{90}$$

where c has been changed to mean the velocity at any section E distant z below A, p being the corresponding pressure.

The quantity flowing per second will be

$$Q = G c_1 = E c = F c'. \tag{92}$$

Substituting in (84) and integrating we have

$$dP = \left(p_1 + \frac{c_1^2}{2g}\gamma\right) dE = \frac{c^2}{2g}\gamma\, dE + z\gamma\, dE$$

or

$$P = \int_F^G dP = p_1 G - p_1 F + \frac{c_1^2}{2g}\gamma G - \frac{c_1^2}{2g}\gamma F$$

$$+ \frac{G^2 c_1^2}{2g}\gamma \frac{1}{G} - \frac{G^2 c_1^2}{2g}\gamma \frac{1}{F} + \gamma \int_F^G z\, dE. \tag{94}$$

By applying (90) to the sum of the second and fourth terms we obtain new-second and new-fourth terms and an eighth term, after which we add the third and fifth, the new-fourth and sixth, and the seventh and eight, respectively, and obtain

$$P = p_1 G - p' F + \frac{G c_1^2}{g}\gamma - \frac{F c'^2}{g}\gamma + \gamma\left(h + \int_F^G z\, dE\right) \tag{96}$$

but the quantity in brackets is easily seen to be the volume of the tapering pipe between A and F so that, using also (92), we have

$$P = p_1 G - p' F + Q\frac{\gamma}{g} c_1 - Q\frac{\gamma}{g} c' + W \tag{98}$$

Regarding now the water in the tapering part of the pipe as a separate body or system we may write—

$P =$ downward pressure on system throughout G + reaction of entering jet + weight of system — upward pressure on system throughout F — reaction of issuing jet,

or, calling the entering jet *negative* and the issuing one *positive* and paying attention to the algebraic signs of the pressures, we may write—

$P = \Sigma$ pressures on system throughout jet sections + Σ jet reactions + weight of system. (100)

In the preceding discussion, we are able to neglect the atmospheric pressure because it is uniform over the whole system, which includes the vessel, though the weight of the system is, of course, the weight in air and not in a vacuum; here, however, the pressures at A and F are different and the vessel, with whatever pressure may be outside of it, is excluded from the system. In comparing results allowance must also be made for the change of sign for forces, the upward direction having there been taken as positive, while here plus forces are those in the direction of the flow and of gravity.

P is the pressure of the water downward against the vessel, or converging part of the pipe; $-P$ is, therefore, the pressure which the vessel exerts upon the system. Transposing P in (100) we get $-P$ and can then include it in the first summation and get the equation in the following form—

$$0 = \Sigma \text{ pressures on the system} + \text{weight of system} + \Sigma \text{ jet reactions.} \qquad (100')$$

In the preceding problem, the jet-reactions were excluded from the external forces acting on the system, and they should be so considered, in accordance with the paragraph (tenth) on the term "reaction," because their action is not really at the boundary of the system, but distributed through it; in equation (100), however, they appear in the guise of external forces acting throughout the sections G and F, so that this equation thus viewed, is simply Σ of vertical forces on the system $= 0$.

Let us now compare (98) with (78). By making $c_1 = v$ and $p' = p_1$ and introducing the vessel, with p_1 outside of it, into the system, allowing at the same time for the change in the signs of forces and in the notation, (98) should become identical with (78). The pressure on the outside of the vessel assists V'' in sustaining it against P, therefore we have

$$P = V'' + p_1 (G - F)$$

as the equation of equilibrium of the vertical forces acting on the vessel, P acting downward and the others upward. Substituting in (98) we get, after cancelling terms,

$$V'' = Q \frac{\gamma}{g} c_1 - Q \frac{\gamma}{g} c' + W \qquad (82')$$

which is the same as (82), allowing for the change in notation;

making now $c_1 = v$ the second member becomes equivalent to the second member of (78), which is therefore a special case of (98), as was to be proved.

By omitting both the weight and pressure, we readily see that (98) gives the value for V when $a = 90°$.

It is an interesting result in mechanics that a vessel of water in a condition of "steady flow" weighs the same as if the water were at rest, which is the same, of course, as a steady flow with $v = 0$.

Regarding such a vessel of water as a system we have an example in inorganic mechanics of what is common in organic structures. A plant, or the body of an animal, is a mechanism which preserves its identity, its form, its weight, its energy, etc., while the matter of which it is composed is constantly changing; in the same way the vessel and the water constitute a permanent mechanism which might prove an interesting subject to discuss from a kinematical standpoint. Such a system, or mechanism, might be called a renovated system, or mechanism.

(*To be continued.*)

BOOK NOTICES.

MODERN AMERICAN METHODS OF COPPER-SMELTING. By Edw. D. Peters, Jr., M.D., M.E., etc, New York: Scientific Publishing Company. 1887.

Dr. Peters has devoted a great part of his busy and useful metallurgical life to the study of copper-smelting, and there is no one better able to speak on that subject than himself. The writer of this review enjoyed three years of his companionship at the School of Mines in Freiberg, Saxony, and has had the pleasure of meeting him afterwards at long intervals at Black Hawk, in Colorado, and at the Ely Copper Mines in Vermont. Wherever Dr. Peters was busy, he was accomplishing much good, and he has usually been busy.

The nucleus of the volume before us appeared in the *Engineering and Mining Journal* some time ago in serial form, as Mr. H. M. Howe's monograph on *Steel* is now appearing in that journal, but it shows every sign of the most careful preparation and intelligent arrangement. Dr. Peters apologizes for not taking up the "Wet Methods" on account of the material addition to the size and cost of the volume which it would entail.

This is the only important want which the volume shows, and is the more emphasized from the fact that the volume is dedicated to Mr. James Douglas, Jr., who, in conjunction with Dr. T. Sterry Hunt, has perfected one of the simplest and best wet processes for the treatment of lean copper ores. But we shall hope that Dr. Peters may be induced later to add a second volume to

his work, which shall be devoted to the wet processes. The first chapter is devoted to some of the localities of copper ores. In this chapter, no attempt has been made to notice the occurrence of copper from the geognostic, but only from the commercial point of view, and hence the native copper occurrences in the orthofelsites of the South Mountain in Pennsylvania, and in the beds of the Merozoic sandstones lying near their junction, not being of commercial significance, are not referred to; though from a geological standpoint they are of great importance. The same is true of the copper deposits in the lower Silurian limestones of Northern Maryland, etc.

Four pages are given to a description of the ores of copper. Twenty pages are dedicated to the methods of copper assaying. Chapter IV devotes forty-five pages to roasting in lump form; Chapter V, twenty-six pages to stall roasting, and Chapter VI, five pages to roasting in lump form in kilns. These three chapters are especially recommended to the copper metallurgist, as they contain a large amount of personal experience of Dr. Peters on a subject to which he has devoted particular attention, and of which the results will not be found elsewhere so concisely and intelligently stated. This is equally true of the following forty-one pages on the calcination of ore and matte in a finely-divided condition; and of the fourteen pages (Chapter VIII), in which the chemistry of this process is treated.

The preliminary ground-work having been finished, a general treatise, in forty-three pages (Chapter IX), considers "Copper Smelting." Thirty pages take up the subject of the brick blast furnace; thirty more are required for the general remarks on smelting in the blast furnace; forty-eight to the reverberatories, and a few pages each are devoted to the "Treatment of Gold- and Silver-bearing Copper Ores," and to "Bessemerizing Copper Matte." Altogether, the book is a valuable addition to metallurgical literature, and will be appreciated both by the student and the practical smelter. P. F.

THE ATOMS OF THE ELEMENTS, OR IRON AND THE OTHER ELEMENTS. By William Coutie. Troy, N. Y.: Author. 1887.

This pamphlet belongs to a class which contemporary science always has difficulty in assigning to its proper place. Either it is a century in advance of modern science in its conclusions, or it is a product of a disordered brain. There is not so much difficulty in treating the methods employed by Mr. Coutie, to establish these startling conclusions, which he says he has arrived at. His English is peculiarly his own as befits such an original work. He says, for example, in his opening sentence: "So much of this is new, that it is difficult to give it a name that will convey what it is, so we name it *double*." After explaining "why we give it (the title?) as iron and the other elements," he adds: "It really *here* is such, and from this it may be most easily understood, corrected and extended." Whether this means that iron is the "other elements," is left in doubt, but even if it be, how it can be "corrected," or "extended," even "*here*," is a mystery, though not more so than how it can be "understood *here*." "Its relations to the ether *is* that the ultimate atoms of all matter constantly give out from the ether those *acts*, known to us as

light, heat, force, chemical action and gravity. All these are but different appearances of this primitive ethereal atomic action." The "its" above, refers to "this paper."

We are told, without any introduction, that "the first and most efficient part of the calculation is the acid, its weight, nature and *atomic* form."

"The weight of carbon was fixed a century ago *by accident*" * * it is "the critical point of the whole. What fixes the weight of carbon where it is is that in our attempts to think like others we lose the power to think for ourselves." (Note.—Mr. Coutie announces as a new discovery that the *weight* of carbon is 3. Of course, he refers to the weight of enough carbon to fix one standard monad atom, which was clearly explained and named "atom-fixing" by Hoffman over twenty years ago, and known and expounded by Gerhard and others long before that.)

He continues: "Where *this*" (scheme of his?) "differs most from present practice, is in that it is not preceded by any theory," etc. He might add, nor followed by any rational conclusion. "Where *this*" (again) "covers most ground, is in that * * * all action becomes the result of this one act—the action of the ether on each one hydrogen atom!" ! !

"Carbon and nitrogen differ from the other elements in that they are composed wholly and directly of hydrogen only, and owe their existence exclusively to their atomic forms."

Here follow geometrical groupings of circles, and more tables, after which this sentence occurs: "Next to the existence of hydrogen, the most important fact in chemistry is the existence of the *acid* (HCH), for it comprises one-half the material universe and holds in subjection under its influence nearly all the other half. It is always combined, and *all its combinations are true elements*. That is, the intensity of its action is greater than our present knowledge."

In the midst of this high science we are treated to an excerpt from the Virginia City *Enterprise* on platinum, under the head-line: "A Mysterious Metal."

Two or three pages follow, professing to discuss gold, atomic heat, heat and air, heat and water. Under "atomic heat" we read with joy that "instead of a *total depravity* of heat, we find that bodies in nature become chemically balanced by outside influences and attain the conditions in which we find them." Heat, then, may hope for an ethereal future, undamned. This golden message should be carried to the public on angel's wings. After some pictures of snow crystals, similar to those of a plate published fifty years ago, we learn that "liquid water is an incompressible *solid* with its atoms free to move in all directions." This seems an unjustifiable attempt to rob Ireland of that industry in which she has had a monopoly for so long, by turning out a cheaper home product of bull. The rest of the pamphlet consists of paragraphs of bourgeois type, following captions, such as "Atomic Volume," "Heat and Life," "Cyanogen and Ammonia." The last paragraph under this latter head is so modest and peculiar that it should be repeated.

"For more than fifty years, the subject has been the pastime pleasure of

my life. But now from it I rest content near to my Maker's feet and view secure the work that is done, for now my day is spent—the goal is reached, the labor is over, the journey is passed, and the victory is won. For now the power that made, moves and maintains the material universe, is opened to human view. Never to close again while truth and manhood are admired among men. The performance of this work will soon become *the brightest jewel in the diadem that crowns the intelligence of North America*, and such it will remain when all that fills its place is passed away and is forgotten. For this is the work of Him whose will we all obey. This is the power by which He called the Sun into being, and this will be His law supreme, where (*sic*) the Sun's race is run, and His work is done and time lays him to rest in never-ending night."

With the startling theology of the last sentence, this imperfect review may terminate without further comment. P. F.

THE METALLURGY OF SILVER, GOLD AND MERCURY IN THE UNITED STATES. By Thomas Egleston, LL D., Prof. of Mineralogy and Metallurgy, School of Mines, Columbia College. In two volumes. Vol. I. John Wiley & Sons. For sale by J. B. Lippincott & Co., Philadelphia.

This work is without any question, in appearance, the largest and most comprehensive that has been attempted in this country, and Prof. Egleston ought to be in many respects better fitted to undertake it than any other. Of course, a book which gives the history of the metallurgical industry, as well as a statement of the processes now in operation, must be largely a compilation, and its value depends greatly on the judgment with which it is compiled. To hold the balance equally between the slower and more accurate processes of the eastern hemisphere and the more rapid and practical methods of the western, requires no little care.

Besides this, what would be good practice in 1860 in one of the remote furnaces of the West, would be very bad practice in 1887, because the commercial side of the problem has been so greatly altered in the intervening time by the change in the surroundings of each furnace, and the difference in the cost of transportation and ways.

It is due to Prof. Egleston to say that he has stated the advantages and disadvantages of the various processes which he cites with commendable impartiality; with a perceptible tendency, however, to recognize the ultimate superiority of the more thorough and scientific method, whether American or not, and whether it is popular among smelters or not. The volume before us gives in an introduction a sketch of the discovery of gold, and a sketch of placer mining. Following this, is a treatise on hydraulic mining. The work commences with the sub-chapter on the treatment of gold quartz, as it would seem that the line between the mechanical and metallurgical treatment of gold is hard to draw. The only three picture illustrations of the volume are in this part. They are coarsely done, though perhaps they illustrate the subject well enough for a volume of this kind. Chapter II is on zinc desilverization; Chapter III is on the separation of gold and silver from copper; Chapter IV is on crushing machinery; Chapter V is on roasting silver ores;

Chapter VI is on the Patio and Cazo processes; Chapter VII is on barrel amalgamation; Chapter VIII is on pan amalgamation; Chapter IX, the treatment of silver tailings; Chapter X, leaching processes.

Each of these chapters should have been an embodiment of a great deal of experience and travel of the author, as well as a generalization which his habits as a teacher might have enabled him to add to the bare statistics. Those things which open to criticism in the book are the matter and the facts, as well as the arrangement, and in some places, the methods of expression.

The title on the cover is open to objection on the ground of English construction—"The Metallurgy of Silver, Gold and Mercury *of* the United States." The object of the investigations is stated to be "for the sake of ascertaining what the real state of the facts *were*." Again: "The spirit of to-day is to recognize no difficulty which, in the *face* of transportation, fuel and water, may not be overcome." "With the limited experience so far, it appears that the value of the mercury lost in amalgamation very much exceeds the expense of waste of chemicals in the Russell process, which are not injurious to health, while mercury is, and allows, at the same time, the extraction of lead and copper as secondary products, which are entirely lost by amalgamation."

The syntax of the above sentences and others throughout the book, is defective, and the meaning of the sentences obscured; but the work is, nevertheless, an imposing and thick contribution to American metallurgical literature. P. F.

THE SUTRO TUNNEL COMPANY AND THE SUTRO TUNNEL; PROPERTY, INCOME, PROSPECTS AND PENDING LITIGATION. Report to the Stockholders. By Theodore Sutro, Attorney, Counsellor, etc., for Sutro Tunnel Company. New York: July, 1887.

This is a neatly-printed work, 8vo, of 185 pages, giving a general account of the great Sutro Tunnel from the time of its commencement, on October 19, 1869, to the present time, when its financial condition seems to be sufficiently desperate, though better than it was. There is nothing of scientific value in the book, the extracts from the testimony of experts being introduced as a lawyer would naturally introduce them—to justify certain points in the chain of narrative of a great law-suit. It will be interesting to the young lawyer and to the general public rather as giving the doubts, fears and struggles of an attorney to overcome obstacles in the way of the success of his clients, and show what may be done in the way of the postponement of decision by the Courts, change of the direction of litigation, and victory over property-wrecking foreign plutocrats by an indefatigable lawyer. P. F.

SCIENTIFIC NOTES AND COMMENTS.

CHEMISTRY.

ANIMAL TANNIN. M. Villon, *Bull. de la Soc. des Elèves* de M. Fremy, through *Chemical News*.—Hitherto there have been known only vegetable tannin with its 800 varieties, and synthetic tannin or digallic acid, not to speak of the so-called mineral tannin, obtained from coal, peat, etc. The author has for a long time sought for an animal tannin, *i. e.*, one formed in the organism of an animal, and appearing either in its secretions or in its tissues. Having been engaged with the weevils, well-known from the damages which they occasion in granaries, he sought for tannin, knowing that, as far back as 1810, M. Penunt, of Lyon, had found gallic acid in these insects.

The corn weevil (*Calandra granaria*) is a coleopterous insect of about three millimetres in length, and of a maroon-brown color. These insects were first killed by exposure to the fumes of chloroform, then ground up and digested for an hour in boiling alcohol at 90 per cent. The extract is decanted into a retort and evaporated on the water-bath to a syrup, and finally dried in a capsule.

The residue is dissolved in acetic ether at 50°; the liquid is filtered, diluted with half its volume of water, and precipitated by means of ammoniacal zinc acetate prepared by dissolving zinc acetate in liquid ammonia diluted with half its volume of water. The first and last portions of the precipitate are rejected.

The precipitate thus obtained consists of zinc tannate, other substances—such as gallic, ellagic acids, phlobaphene, albuminoids, and pectic principles—remaining in solution.

The precipitate is then suspended in water, to which oxalic acid has been added sufficient to throw down all zinc. The mixture is heated nearly to a boil whilst stirring. The tannin remains in solution; the liquid is evaporated to a syrup in a vacuum at a temperature of 50° to 60°. Five hundred parts of weevils yielded fifteen parts of pure tannin.

Animal tannin (fracticornitannic acid) appears in the form of small reddish-yellow scales, soluble in water, aqueous ether, alcohol, chloroform, etc. It possesses all the general properties of the tannins, precipitating gelatin, albumen, and dissolved caseine, and being absorbed by animal tissues.

It precipitates the natural and artificial alkaloids, and gives a bluish-black coloration with ferric salts. Its analysis leads to the formula $C_{28}\ H_{16}\ H_{16}$. Sulphuric acid splits it up into glucose, gallic acid, and an amorphous red product analogous to phlobaphene. H. T.

ANALYSES OF SOME TANNIN MATTERS. (P. Kay and E. Bastow, *Journal of the Society of Dyers and Colourists*, **3**, 9.)—The following analyses of some of the tannin materials, exhibited in the Indian and Colonial Exhibition, 1886, were done during the Session 1886–87. All the estimates were carried out in duplicate by each of us, working independently, by Proctor's modification of Löwenthal's method. The percentages of tannin are given below in terms

of oxalic acid on the one hand, and in terms of gallotannic on the other, each figure representing the mean of four separate estimations:

No.	Name.	Percentage of Tannin	
		In Terms of Oxalic Acid.	As Gallotannic Acid.
1	Terminalia tomentosa (galls),	9·24	6·53
2	" belerica (fruit),	12·86	8·48
3	" chebula "	52·65	34·49
4	Ceriops Roxburghiana (bark),	37·65	24·66
5	Camia auriculata,	19·94	12·86
6	Acacia catechu (extract),	76·00	. . .
7	" " (bark),	21·35	. . .
8	" arabica (pods),	22·44	. . .
9	Areca catechu (nuts),	14·28	. . .

The percentages of gallotannic acid are calculated from those of oxalic acid by Neubauer's equivalent. H. T.

Free Thiocyanic Acid.—Peter Klason (*Jour. Prakt. Chemie*, **35**, 400,) has succeeded in preparing thiocyanic acid by distilling in vacuo a ten per cent. aqueous solution of the acid, drying the vapor by passage over calcium chloride and then condensing in a freezing mixture. The condensed liquid is pale yellow, and soon after the receiver containing it is taken from the cooling mixture, solidifies to an amorphous yellow mass. If a few drops of the still liquid substance be placed in a watch glass, they disappear as rapidly as ether, the anhydrous acid being very volatile and having a penetrating odor. In its behavior it closely resembles free cyanic acid; at low temperatures both are volatile, strongly odorous liquids that become polymerized at a higher temperature, at the same time disengaging heat. When perfectly dry, both appear to be imido-compounds, but in solution they exist as oxy-compounds. A dilute aqueous solution of thiocyanic acid may be most easily prepared by the action of sulphuric acid on barium thiocyanate. W. H. G.

The Reaction of Ammonia on Bleaching Powder, and the Constitution of Chlorinated Lime. G. Lunge and R. Schoch (*Berl. Ber*, **20**, 1474).—The authors point out that the reaction between ammonia and chlorinated lime as explained by Dreyfus requires the co-existence of calcium hydroxide and ammonium chloride as products, an evident impossibility. Analytical experiments show that, as had been advanced by Kolb, the products of the reaction are calcium chloride, water and nitrogen. The objections to the formula $Ca\,Cl^2\,O$ for chlorinated lime, which were advanced by Dreyfus, are therefore unfounded. Kolb proposed the use of ammonia as an antichlor, but the destruction of traces of chlorine by ammonia is complete only after several days in the cold, unless an excess of thirty times the absolutely required quantity of ammonia be employed. Since the actual quantity of bleaching powder that remains to be destroyed is exceedingly small, even thirty times the required quantity of ammonia fortunately represents but a small absolute quantity. W. H. G.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, November 16, 1887.*]

HALL OF THE INSTITUTE, NOVEMBER 16, 1887.

JOSEPH M. WILSON, President, in the Chair.

Present, 152 members and forty visitors.

Additions to membership since last meeting, thirty-three.

The Special Committee on Government Scientific and Engineering Bureaux made a report of progress.

Mr. JOHN L. GILL, Jr., read a paper on "Screw-Threads," in which he discussed the comparative merits of the ordinary V, the Whitworth, and the Sellers thread, and called attention to certain alleged deficiencies of the existing systems. He proposed as a substitute, a thread having one side 90° and the other 60°, flat at top and bottom, with eight threads to the inch, and two-eighths taken from top and bottom. He presented the results of a series of tests of the strength of this form of thread as compared with the other forms, which were favorable to the new thread, and exhibited the tested specimens. The paper has been referred to the Committee on Publications.

Mr. FRED. E. IVES made some remarks upon the so-called Japanese Magic Mirrors. He reviewed the explanations that had been offered to explain the curious property which they exhibit, and offered what he believed to be the proper explanation. Referred for publication.

Mr. JOHN CARBUTT exhibited a number of photographs made with the "flash light" mixture referred to in the proceedings of the October meeting.

Mr. CYRUS CHAMBERS, Jr., exhibited and described some improvements to the portable photographic camera which he had devised, and which add to its convenience. They embraced an adjustable tripod, an instantaneous and "time" shutter, and a collapsing focusing-hood.

Prof. EDWIN J. HOUSTON spoke in general terms of the attempts that had been made to devise apparatus for recording and reproducing speech, referring specially to the "phonograph" of Mr. Edison, and to the published statements respecting alleged improvements that the inventor had succeeded in making, and which would make it a useful apparatus. He also referred to the "gramophone," devised by Mr. Emile Berliner, for accomplishing the same objects, and described the instrument with the aid of a picture of the same, projected on the screen.

Adjourned.

WM. H. WAHL, *Secretary.*

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Bound in Wheat

PENNSYLVANIA STATE WEATHER SERVICE.

SEPTEMBER, 1887.

SUMMARY OF METEOROLOGICAL REPORTS

MADE BY VOLUNTARY OBSERVERS,

——TO THE——

METEOROLOGICAL COMMITTEE OF THE

FRANKLIN INSTITUTE,

PHILADELPHIA, PA.

T. F. TOWNSEND, Sgt. Signal Corps, Assistant.

PENNSYLVANIA STATE WEATHER SERVICE BULLETIN FOR SEPTEMBER, 1887.

HALL OF THE FRANKLIN INSTITUTE.

PHILADELPHIA, October 1, 1887.

This summary of the meteorological reports of the State Observers is not in the form or style intended when the organization is completed. From various causes many unavoidable delays have occurred, and it will yet take time to place the Service on the basis contemplated. In order that the meteorological data of the State may be thoroughly reliable, the best instruments have been secured, and special attention paid to their exposure. Every effort has been made to secure the co-operation of colleges and schools, that students may have all the advantages possible for obtaining a meteorological education. Many of these have already made arrangements to aid in the work, and will soon furnish the Service with full reports. As their fall terms did not commence till September, their observations for this month are incomplete. This work requires some practice before proficiency is acquired, and time must be given to attain it.

About thirty counties are now supplied with instruments of the Signal Service pattern, consisting of maximum and minimum thermometers, dry and wet thermometers, rain gauges and instrument shelters, and the rest are being provided for as fast as the instruments can be made and observers secured. Some displaymen have been obtained for the Weather Signals, and this portion of the work will soon be vigorously pushed forward. The territory to be covered is a large one, and all the aid possible is needed to secure desirable results.

It is not expected that the small appropriation by the State should enable the Committee to display the signals throughout the counties. It is hoped that after the original display stations are established in each county, the people will organize and attend to the erection and maintenance of repeating stations, which, being for the benefit of the people of each county, ought to be at their expense.

Observers are particularly requested, when possible, to give all the data called for on the forms, and to complete and mail them as soon after the end of the month as is practicable, that the work of publication may not be delayed. As soon as the data will warrant it a larger review will be issued, which will contain all matters of interest reported.

A regular commission, signed by the proper authority of the State, will be given to all observers whose reports, after examination, are found satisfactory.

Observers are requested to paste newspaper cuttings containing meteorological data in their original record books, under proper dates.

The Committee on Meteorology of the FRANKLIN INSTITUTE,
W. P. TATHAM, *Chairman.*

REMARKS.—The weather for September in Pennsylvania has been slightly colder than the average, and has ranged from nearly normal in the Western portion to about 3° below in the Eastern portion. The mean temperature for the state was 60°. This, as compared with last September, is between 4° and 5° lower.

About the usual differences have occurred between the tide water sections and the elevated districts.

Rather more than the average amount of cloudiness has prevailed.

The rain fall has averaged about three inches as a whole. The greatest rainfall reported was at West Chester, and amounted to 5·67 inches.

The heaviest rains occurred on the 11th and 12th, and were quite general throughout the State. Heavy rains were also reported on the 28th and 29th in the eastern counties.

The month has been less stormy than usual, and with a small proportion only of windy days. There has been no severe general storm attended with great changes of pressure and profuse rainfall in the eastern counties, as often occurs in September.

The barometer has ranged high, and the monthly mean is above the normal. The mean at Philadelphia being 30·110, Pittsburg, 30·075, and Erie, 30·100.

While light frosts were reported on low lands during the first and middle of the month, vegetation was vigorous and generally uninterrupted, until it was suspended by the cold and frost of the 25th and 26th.

At this time corn was everywhere fairly ripened, but tobacco, buckwheat, and some vegetables were still growing.

These frosts were anticipated by the Chief Signal Officer, and warnings were sent to the tobacco districts.

The wheat seeding season has been favorable, the ground in good condition, and the crop at this date fairly started. The late crop of hay is generally good in the eastern counties.

The fruit crops of the state are gathered so early that they are not subject to risk from frost, except in a few northern districts.

A slight earthquake shock was noticed on the 1st at Norristown, which was also reported felt at some points eastward.

Lunar halos were noticed on the 3d, 6th, 7th, 11th, 20th, 26th, 30th.

Solar halos on the 6th, 11th, 18th, 26th. Thunder storms occurred on the 6th, 7th, 11th, 13th, 18th, 22d, 29th, 30th. That of the 7th was quite general and at Shamokin and Dyberry was attended with hail. An aurora was reported from Indiana on the 25th.

T. F. T.

MONTHLY SUMMARY OF REPORTS BY VOLUNTARY OBSERVERS OF THE PENNSYLVANIA STATE WEATHER SERVICE FOR SEPTEMBER, 1887.

Station,	County.	Temperature.								Precipitation.		Observers.
		Monthly Mean.	Mean of Maximum.	Mean of Minimum.	Maximum.		Minimum.		Monthly Range.	Total Inches.	Number of Days Rainfall.	
					Highest.	Date.	Lowest.	Date.				
Philadelphia,	Philadelphia,	64·0	72·1	57·4	85·7	7	42·4	25	43·3	4·92	12	L. M. Dey, Sgt. Sig. Corps.
Pittsburgh,	Allegheny,	65·1	74·3	55·0	92·0	13	36·0	26	56·0	2·03	14	O. D. Stewart, Sgt. Sig. Corps.
Erie,	Erie,	60·0	69·7	51·6	92·0	13	37·5	26	54·5	3·17	16	Peter Wood, Sgt. Sig. Corps.
West Chester,	Chester,	61·3	69·7	53·9	84·0	7	37·0	25	47·0	5·67	12	Dr. J. C. Green.
Altoona,	Blair,	62·1	73·3	51·0	83·0	7, 15	36·0	24, 25	47·0	2·96	8	C. B. Dudley.
Shamokin,	Northumberland,	57·0	70·0	47·0	84·0	7, 14	29·0	26	55·0	3·00	8	G. R. Hanley.
McConnellsburg,	Fulton,	60·1	72·9	. . .	84·0	2, 7, 14	30·0	27	54·0	4·77	12	Thomas F. Sloan.
Fallsington,	Bucks,	60·2	70·5	53·5	85·0	7	39·0	25	46·0	4·14	8	Milnor Gillingham.
Dyberry,	Wayne,	54·7	65·8	43·0	78·0	14	27·0	26, 27	51·0	2·28	7	Theo. Day.
Pottstown,	Montgomery,	61·0	70·3	54·0	85·0	7	39·0	26	46·0	4·78	5	Dr. Charles Moore.
Quakertown,	Bucks,	58·4	69·5	52·2	84·5	7	33·0	26, 27	51·5	3·52	10	J. L. Heacock.
Ridgway,	Elk,	55·5	70·0	40·7	85·0	13	27·0	28	58·0	1·60	5	Joe Messinger.
Clarion,*	Clarion,	55·0	67·0	46·0	87·0	13	27·0	26	60·0	2·14	6	Prof. J. H. Apple.
Indiana,†	Indiana,	58·4	69·8	48·7	90·0	13	28·0	26	62·0	2·56	5	Prof. Albert E. Maltby.
Carlisle,‡	Cumberland,	63·2	. . .	. . .	83·0	3	38·0	26	45·0	3·83	10	J. E. Pague.
Easton,	Northampton,	. . .	. . .	. . .	. . .	. . .	34·0	26	. . .	3·24	6	Prof. J. W. Moore.
State College,	Centre,	59·4	. . .	. . .	82·0	5, 14	32·0	25	50·0	3·69	6	Prof. Wm. Frear.
Blooming Grove,	Pike,	56·8	. . .	. . .	85·0	14	28·0	26	57·0	2·00	5	John Grathwohl.
Bethlehem,	Northampton,	61·0	69·	50·	84·0	7	34·0	20	50·0	2·76	8	Lerch & Rice.
Wellsboro,	Tioga,	. . .	. . .	. . .	78·0	7	26·0	26	52·0	2·42	10	H. D. Deming.

* 10 to 30, 21 days. † 11 to 30, 20 days. ‡ 1 to 14, 19 to 30, 26 days.

T. F. Townsend,
Sergeant Signal Corps, Assistant.

PENNSYLVANIA STATE WEATHER SERVICE.

OCTOBER, 1887.

SUMMARY OF METEOROLOGICAL REPORTS

MADE BY VOLUNTARY OBSERVERS,

—TO THE—

METEOROLOGICAL COMMITTEE OF THE

FRANKLIN INSTITUTE,

PHILADELPHIA, PA.

T. F. TOWNSEND, Sgt. Signal Corps, Assistant.

PENNSYLVANIA STATE WEATHER SERVICE BULLETIN FOR OCTOBER, 1887.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 1, 1887.

It will be perceived, on examination of the annexed monthly summary, that the number of observing stations has been increased to thirty-two this month, against twenty for the last, and that the summary now includes barometrical observations in certain localities.

As a general thing, the records appear to be carefully made, and it would tend greatly to the accuracy of the results if each observer would add up his columns and calculate the means. These calculations should be repeated and checked at the general office.

Several of the observers attach interesting and instructive notes of the condition of the crops as affected by the weather, and also of special phenomena. That these notes are valuable as a permanent record, will appear hereafter and it is hoped that all of the observers may give them as fully as the space on blanks will admit. A review by each observer of the general results at his station for the month will add to the value of his report.

Observers will find it interesting to compare their results with those of other stations, and thus to establish their relative portion for each month as respects the principal features of the weather.

Observers are particularly requested to give all the data called for on the forms, and to complete and mail them promptly, so that the publication may not be delayed.

The Committee repeat the expression of the hope that the people of each county will organize for the purpose of flagging their county so as to convey promptly to all the farmers, the daily forecasts of the weather for the next twenty-four hours. A little reflection will show the necessity for this. The repeating stations do not repeat the signal for their own benefit, but for that of the people beyond them, who, in turn, pass their signals to their more distant neighbors.

Where some do the work and others reap the benefit, a system of proper compensation is necessary, and this can only be attained by organization.

For the Committee on Meteorology of the FRANKLIN INSTITUTE,
W. P. TATHAM, *Chairman.*

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weath

County.	Station.	Barometer.			Temperature.											Relative Humidity.	Dew Point.	Total Inches.
						Maximum.		Minimum.				Daily Range.						
		Mean.	Highest.	Lowest.	Mean.	Highest.	Date.	Lowest.	Date.	Mean of Maximum.	Mean of Minimum.	Greatest.	Date.	Least.	Date.			
Allegheny,	Pittsburgh,	30·003	30·430	29·570	53·0	80·3	7	20·	31	62·1	43·8	32·9	16	9·	. . .	68·9	42·3	0·39
Bedford,	Charlesville,	. . .	. . .	. . .	47·2	76·	. . .	16·	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Bradford,	Wysox,	. . .	. . .	. . .	47·6	73·	8	16·	31	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	1·50
Bucks,	Quakertown,	30·057	30·444	29·625	49·1	82·2	8	23·	16	61·8	37·6	37·	16	7·7	28	77·	42·3	1·79
Bucks,	Fallsington,	30·038	30·502	29·556	50·9	80·	8	29·	16	60·6	43·0	31·	16	4·	1	83·7	36·1	3·06
Cameron,	Emporium,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Centre,	Phillipsburg,	. . .	. . .	. . .	43·3	78·	19	10·0	31	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0·35
Centre,	State College,	30·099	30·545	29·625	48·5	78·	7	18·	31	57·6	38·2	37·	31	10·	2, 5, 27	76·9	41·6	0·46
Chester,	West Chester,	30·049	30·441	29·655	52·0	83·5	8	26·	31	61·6	44·3	30·	7	4·	28	. . .	. . .	1·76
Clarion,	Clarion,	. . .	. . .	. . .	45·4	78·	8	14·	31	58·1	36·8	38·	23	11·	2	71·3	36·3	1·16
Columbia,	Catawissa,	. . .	. . .	. . .	. . .	80·	8	17·5	31	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0·56
Crawford,	Meadville,	30·085	30·415	29·635	50·1	75·	7, 8	30·	31	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Cumberland,	Carlisle,	. . .	. . .	. . .	51·8	83·2	9	28·0	31	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	1·32
Delaware,	Swarthmore,	30·067	30·467	29·531	52·0	85·1	8	27·3	31	61·6	43·8	33·1	8	4·	28	75·1	44·2	1·02
Elk,	Ridgway,	. . .	. . .	. . .	45·0	79·	8	12·	31	56·9	29·2	49·	19	10·	4, 5	85·3	42·0	0·90
Erie,	Erie,	30·020	30·470	29·480	48·9	79·	7	25·8	31	. . .	. . .	28·7	. . .	4·5	. . .	77·0	41·7	4·43
Fayette,*	Uniontown,	30·010	30·376	29·647	52·4	77·	8	20·	31	62·7	40·8	40·	21	10·	3	72·2	40·4	2·23
Fulton,	McConnellsburg,	. . .	. . .	. . .	49·9	85·	10	23·	16, 26, 31	62·4	38·2	41·	7	10·	27	80·3	42·4	0·59
Huntingdon,*	Huntingdon,	. . .	. . .	. . .	48·0	83·5	7	13·5	31	61·8	35·5	47·8	17	7·	28	77·5	40·1	0·31
Indiana,	Indiana,	. . .	. . .	. . .	47·6	79·8	7	11·	31	59·0	36·4	40·	16	11·	5	82·7	42·3	0·64
Lackawanna,†	Scranton,	. . .	. . .	. . .	44·2	71·	17	18·	31	55·8	33·0	39·	17	8·	28	89·7	41·7	1·04
Luzerne,	Drifton,	. . .	. . .	. . .	46·2	83·	. . .	32·	. . .	68·0	47·	. . .	. . .	. . .	. . .	. . .	. . .	2·37
Lycoming‡	Williamsport,	. . .	. . .	. . .	48·0	79	8	17	31	. . .	40·	. . .	. . .	. . .	. . .	72·8	38·9	1·10
Mercer,§	Greenville,	. . .	. . .	. . .	41·5	72·9	17	17·	31	44·2	29·3	38·6	17	14·	30	76·	33·3	0·32
Montgomery,	Pottstown,	. . .	. . .	. . .	51·5	82·	8	26·	31	61·3	43·7	. . .	. . .	. . .	. . .	75·4	44·9	1·40
Northampton,	Bethlehem,	30·010	30·464	29·531	52·0	82·	8	23·	31	61·	42·	33·	13, 16	9·	22, 25	89·	48·3	1·12
Philadelphia,	Philadelphia,	30·040	30·490	29·580	55·6	84·2	8	30·6	31	64·0	48·8	26·6	8	6·7	25	66·2	43·6	1·68
Pike,	Blooming Grove,	. . .	. . .	. . .	46·4	82·	8	17·	31	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	2·40
Schuylkill,	Girardville,	. . .	. . .	. . .	49·5	82·	7	21·	31	61·6	40·6	38·	7	8·	20	. . .	. . .	1·16
Somerset,	Somerset,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Tioga,	Wellsboro,	. . .	. . .	. . .	45·3	80·	. . .	15·	. . .	57·	39·1	. . .	. . .	. . .	. . .	. . .	. . .	2·54
Washington,*	Washington,	. . .	. . .	. . .	49·2	74·	8	15·	31	. . .	39·4	. . .	. . .	. . .	. . .	. . .	. . .	·77
Wayne,	Dyberry,	. . .	. . .	. . .	46·2	77·	8	14·	31	56·4	34·6	38·	16	6·5	1	. . .	. . .	1·24
Westmoreland,*	Greensburg,	. . .	. . .	. . .	46·8	78·	7	13·	31	59·9	35·5	49·9	17	9·	5	84·5	41·7	·64

* 3d to 31st, 29 days. † 9 to 31, 23 days. ‡ 6 to 31, 26 days. § 11 to 31, 21 days.

ERS OF THE PENNSYLVANIA STATE WEATHER SERVICE FOR SEPTEMBER, 1887.

Daily Range.				Relative Humidity.	Dew Point.	Precipitation.				Wind.	Number of Days.		O
Greatest.	Date.	Least.	Date.			Total Inches.	Greatest in 24 Hours.	Date.	Number of Days Rainfall.	Prevailing Direction.	Cloudy.	Frost Occurred.	
32·9	16	9°	. . .	68·9	42·3	0·39	·20	10	9	N	11	7	Oscar D. Ste
. . .	. . .	. . .	. . .	. . .	.	0·52	·17	. . .	6	. . .	. . .	. . .	Rev. A. Tho
. . .	. . .	. . .	. . .	. . .	. . .	1·50	·57	9	8	NW, W	23	11	Charles Beec
37°	16	7·7	28	77°	42·3	1·70	·45	20	12	NE, W	10	10	J. L. Heacoc
31°	16	4°	1	83·7	56·1	3·06	2·33	20	9	SW, NW	10	2	Milnor Gillin
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . . . .
. . .	. . .	. . .	. . .	. . .	. . .	0·35	·18	21	4	S	. . .	4	L. Ray Morg
37°	31	10°	2, 5, 27	76·9	41·6	0·46	·14	3	8	W	21	3	Prof. Wm. F
30°	7	4°	28	. . .	. . .	1·76	·79	20	12	. . .	6	. . .	Jessie C. Gre
38°	23	11°	2	71·3	36·3	1·16	·32	10	10	SW	12	4	J. H. Apple,
. . .	. . .	. . .	. . .	. . .	. . .	0·56	. . .	. . .	. . .	. . .	. . .	. . .	Wm. G. Vet
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	SW	9	. . .	Prof. J. H. I
. . .	. . .	. . .	. . .	. . .	. . .	1·32	·38	21	5	W	5	4	J. E. Pague.
33·1	8	4°	28	75·1	44·2	1·62	·74	20	5	NW	13	. . .	Prof. Susan
49°	19	10°	4, 5	85·3	42·0	0·90	·60	3	2	. . .	. . .	. . .	Joe Messinge
28·7	. . .	4·5	. . .	77·0	41·7	4·43	. . .	. . .	17	NW	10	3	Peter Wood,
40°	21	10°	3	72·2	40·4	2·23	·90	13	6	NW	8	9	Wm. Hunt.
41°	7	10°	27	80·3	42·4	0·59	·16	27	9	W, NW	9	5	Thomas F. S
47·8	17	7°	28	77·5	40·1	0·51	·16	11	5	W	10	8	Prof. W. J.
40°	16	11°	5	82·7	42·3	0·64	. . .	. . .	8	N	13	9	Prof. Albert
39°	17	8°	28	89·7	41·7	1·04	·41	11	9	NW	9	5	T. F. Heebn
. . .	. . .	. . .	. . .	. . .	. . .	2·37	·95	. . .	10	. . .	12	. . .	H. D. Miller
. . .	. . .	. . .	. . .	72·8	38·9	1·10	·35	1	6	W	14	6	E. H. Baker
38·6	17	14°	30	76°	33·3	0·32	. . .	. . .	5	. . .	8	11	Prof S. H.
. . .	. . .	. . .	. . .	75·4	44·9	1·40	·85	21	5	NW, W	. . .	4	Charles Moo
35°	13, 16	9°	22, 25	89°	48·3	1·12	·84	20	6	NW	5	5	Lerch & Ric
26·6	8	6·7	25	66·2	43·6	1·68	1·49	20, 21	9	W	13	3	Luther M. D
. . .	. . .	. . .	. . .	. . .	. . .	2·40	1·20	11	6	S	·5	. . .	John Grathv
38°	7	8°	20	. . .	. . .	1·16	·32	20	7	. . .	. . .	. . .	E. C Wagn
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . . . .
. . .	. . .	. . .	. . .	. . .	. . .	2·54	1·16	. . .	10	SW	22	13	H. D. Derri
. . .	. . .	. . .	. . .	. . .	. . .	·77	. . .	. . .	4	. . .	. . .	6	Harrison Ou
38°	16	6·5	1	. . .	. . .	1·24	·26	1	10	. . .	. . .	13	Theodore D
49·9	17	9°	5	84·5	41·7	·64	·35	10	9	NW	11	9	H. S. Bruno

T. F. TOWNSEND,
Sergeant Signa

ate of the State for October has been from 2° to 5° colder
in the western and elevated counties. The cold of the
31st was quite general, and nearly all the western and
ort snow on the 21st and 22d, in amounts from "ground
h at Scranton and Wellsboro, and four inches at Green-
on was cut off throughout the State by the killing frost
although in some of the Eastern and Southern counties,
lleys, the hardier sorts were continued until the severe
d during the latter half of October, and from which no
n abundant growth of fall wheat and grass has been

f highlands had a mean of 45° at observed stations, and
gher surfaces. The central counties had an average of
ons, with a very considerable area of 50° in the valleys,
Chester, Swarthmore, Uniontown, Pottstown and Carlisle,
d 55°·6 at Philadelphia, which is not a full degree below
ies of years. The mean at Erie was 48° 9, and therefore
al mean of 53°·3.

he Lake Shore was probably not so much extended as
severe frosts in September and October. None of these
caused or attended by general storms of severity. The
bly free from storms or floods, the rainfall being generally
stern part of the State is reported as very dry. In West-
e scarcity of water in wells and cisterns is causing much
several posts of observation, the rainfall was less than an
State College, Ridgway, McConnellsburg, Huntingdon,
, Washington, Greensburg, Catawissa, Charlesville, and
nd Fallsington were exceptional with 4·43 inches, at Erie
gton. The number of rainy days varied from four to
ge for the State being seven. A severe wind storm from
west occurred in Greensburg, Greenville, Clarionville,
and Scranton on the evening of the 23d. The general
ent for the month was rather less marked than usual, and
occurred east of the Alleghany's, as often happens in

re observed at Quakertown on the 1st, Indiana 27th,
8th. Wild geese were observed flying south on 22d and
, 25th at Doylestown and Dyberry, and on the 27th at
observer at Quakertown reports plum trees in blossom on
trees on the 25th, in protected situations. The ground
stations on the morning of the 31st. T. F. T.

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NSEND,
rgeant Signal Corps, Assistant.

The general climate of the State for October has been from 2° to 5° colder than usual, especially in the western and elevated counties. The cold of the 15th, 22d, 26th and 31st was quite general, and nearly all the western and northern counties report snow on the 21st and 22d, in amounts from "ground covered" to one inch at Scranton and Wellsboro, and four inches at Greenville. Most vegetation was cut off throughout the State by the killing frost of September 26th, although in some of the Eastern and Southern counties, and in the lower valleys, the hardier sorts were continued until the severe frosts, which occurred during the latter half of October, and from which no district was free. An abundant growth of fall wheat and grass has been reported

The colder belt of highlands had a mean of 45° at observed stations, and about 40° for the higher surfaces. The central counties had an average of 47° at observed stations, with a very considerable area of 50° in the valleys, and of 52° at West Chester, Swarthmore, Uniontown, Pottstown and Carlisle, 53° at Pittsburgh, and 55°·6 at Philadelphia, which is not a full degree below the average for a series of years. The mean at Erie was 48° 9, and therefore 4°·4 below the general mean of 53°·3.

The season at the Lake Shore was probably not so much extended as usual, owing to the severe frosts in September and October. None of these changes were either caused or attended by general storms of severity. The month was remarkably free from storms or floods, the rainfall being generally light. The southwestern part of the State is reported as very dry. In Westmoreland County the scarcity of water in wells and cisterns is causing much inconvenience. At several posts of observation, the rainfall was less than an inch, as Pittsburgh, State College, Ridgway, McConnellsburg, Huntingdon, Indiana, Greenville, Washington, Greensburg, Catawissa, Charlesville, and Phillipsburg. Erie and Fallsington were exceptional with 4·43 inches, at Erie and 3·06 at Fallsington. The number of rainy days varied from four to seventeen, the average for the State being seven. A severe wind storm from the southwest and west occurred in Greensburg, Greenville, Clarionville, Indiana, Meadville and Scranton on the evening of the 23d. The general atmospheric movement for the month was rather less marked than usual, and no northeast storm occurred east of the Alleghany's, as often happens in October.

Lunar halos were observed at Quakertown on the 1st, Indiana 27th, Clarion 27th and 28th. Wild geese were observed flying south on 22d and 26th at Quakertown, 25th at Doylestown and Dyberry, and on the 27th at Greensburg. The observer at Quakertown reports plum trees in blossom on the 14th, and apple trees on the 25th, in protected situations. The ground was frozen at most stations on the morning of the 31st. T. F. T.

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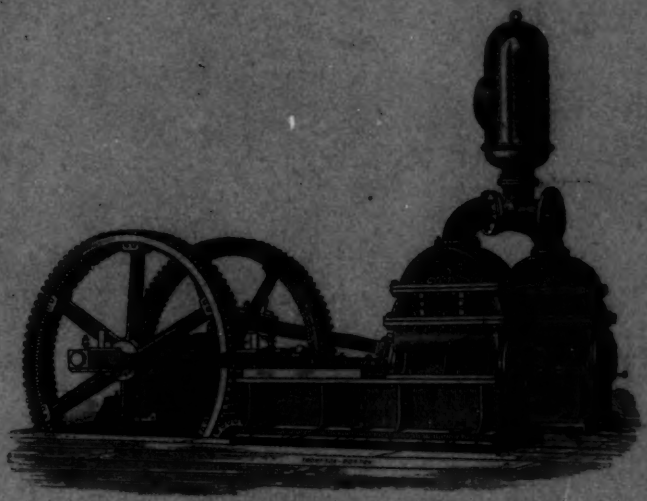

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